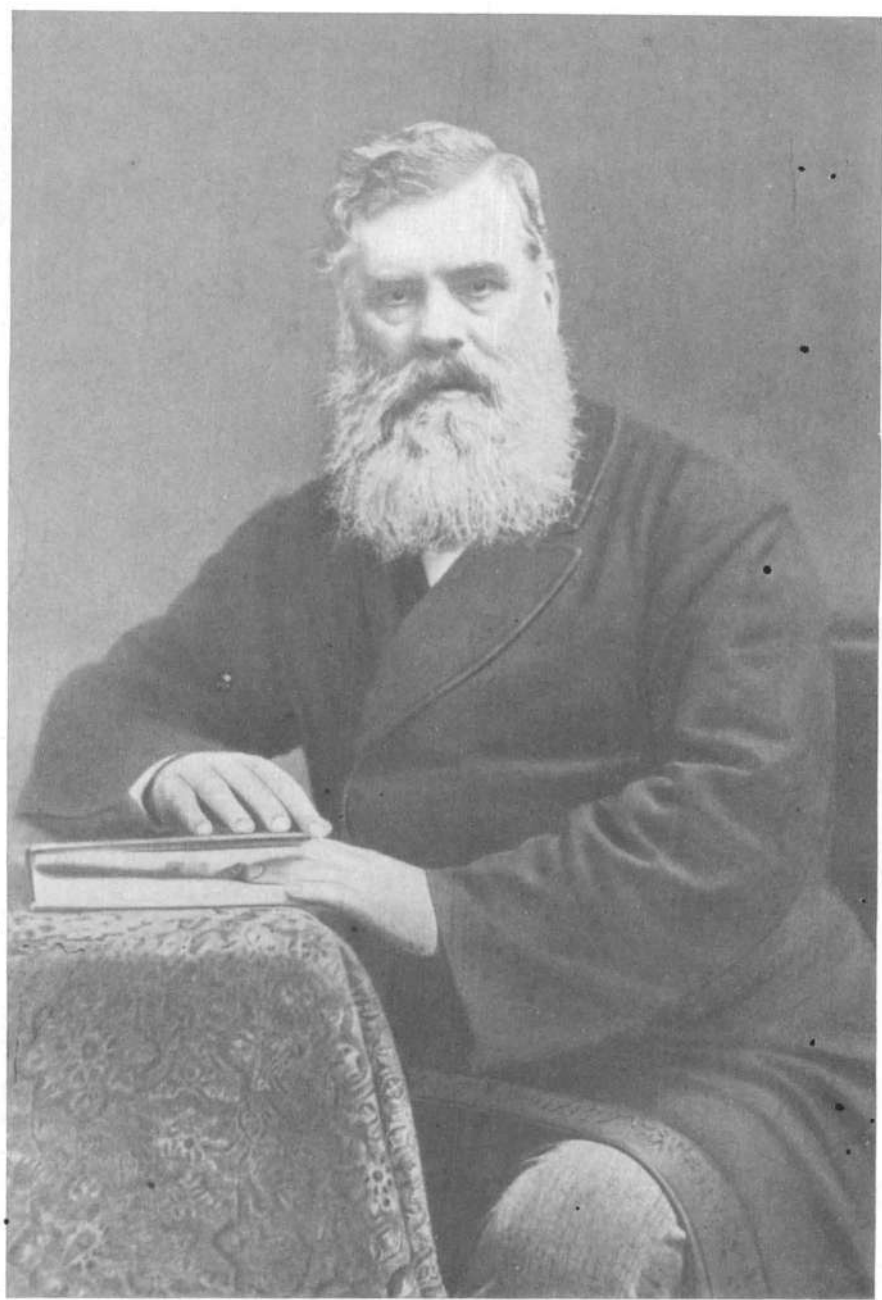


**CENTENARY
OF THE
GEOLOGICAL SURVEY OF INDIA
1851—1951**



**A SHORT HISTORY
OF THE
FIRST HUNDRED YEARS**

1951



T. OLDHAM

FOREWORD

When it was decided to celebrate the Centenary of the Geological Survey of India, Sir Lewis Fermor and Sir Cyril Fox, former Directors of the Survey, were invited to write the history of the Department, and they kindly agreed to do so. Subsequently Sir Cyril Fox found himself unable to undertake his portion of the task, owing to travels abroad, and Sir Lewis Fermor agreed to write the whole, and has completed the portion covering the first twenty-five years.

It was also decided that the full history should be published after the termination of the celebrations, so that an account of the latter might be included, and that a shorter version should be prepared and issued at the time of the commemoration.

The short history given in the following pages has been written by J. B. Auden, P. K. Ghosh, Sr., A. M. N. Ghosh and A. G. Jhingran, and has been seen through the press by P. K. Ghosh, Jr. In writing the portion covering the first twenty-five years the authors have utilised Sir Lewis Fermor's manuscript. For various reasons the history of the subsequent seventy-five years has had to be written hurriedly, and it is hoped that any uneven treatment and blemishes that it may contain will be excused.

The Department's thanks are due to Mr. E. V. Gregory, Controller of Printing and Stationery, for having made it possible to print this short history in time.

The Department also records its grateful acknowledgements to the Survey of India, particularly their Photo Litho Office, for their co-operation in the preparation of some of the plates; and to Messrs. Swastika Press Ltd., for the care they have taken in printing all the Centenary publications in such a short time.

W. D. WEST,

Director,

Geological Survey of India.

CALCUTTA,

The 1st January, 1951.

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INTRODUCTION

In compiling the history of a Department there is a temptation to divide it into periods corresponding to those during which its Directors held office. In the case of a scientific department, however, the better course would be to write the history around the main scientific conceptions that arose during the progress of the work, for it is these that largely determine the course of further discovery rather than the more accidental matters of seniority and promotion. Nevertheless, to do this in the case of the history of the Geological Survey of India would require more time than has been available, and in the circumstances the easier course has had to be followed.

The long period from the days of Williams and Oldham to the present time has been characterised by great changes in the conditions of geological field work. This change has been due in the main to two causes: the progressive opening up of the country with the extension of roads and the introduction of railways and telegraphs; and the vast strides made in the knowledge of tropical diseases, particularly of the cause and treatment of malarial fever.

In the days of Williams and for some decades afterwards the most important aids to transport were those that had prevailed in India for centuries, namely the elephant, the bullock cart, the camel, the horse and the coolie; and it is recorded that the Geological Survey built up its own herd of elephants, officers setting out from Calcutta by road with their baggage on elephants and themselves mounted either on elephants or on horses. In fact tradition has it that some of these elephants were trained to pick up pieces of rock and hand them up to master for his inspection.

In the early years, before the cause and treatment of tropical diseases were known, the mortality of those who went into the jungle was very high, and in one annual report Oldham records that up to date the average duration of life

in the Geological Survey was only a fraction more than nine years. In fact the losses of the staff in the early years were so serious that Oldham records in the annual report for 1870 that Assurance Offices declined to accept the insurances on the lives of officers of the Survey, stating that 'no premium whatever could cover the risk'.

Early Geological Maps

The first three geological maps of parts of India were made of the Hyderabad region by Dr. H. W. Voysey (1820), of Malwa by Captain P. Dangerfield (1824), and of the western Himalaya by Captain J. D. Herbert (1825). Dr. Voysey may indeed be regarded as the Father of Indian Geology. Brought out as a Surgeon to the Great Trigonometrical Survey of India, between 1818 and 1823 he made important contributions to the geology of central and southern India, and put forward the illuminating suggestion of Lambton of the Survey of India that the geological nature of the terrain may affect the plumb line. He contracted fever while on his way from Nagpur to Calcutta, and arrived at Howrah dead in his *palki* (1823).

Dangerfield served under Sir John Malcolm in Central India during 1820 and 1821, making meteorological, geographical, astronomical and geological observations.

Herbert was given the pleasant title of 'Geological Surveyor of the Hymalya Mountain', and in 1825 prepared a geological map of the area between the Sutlej and Kali rivers.

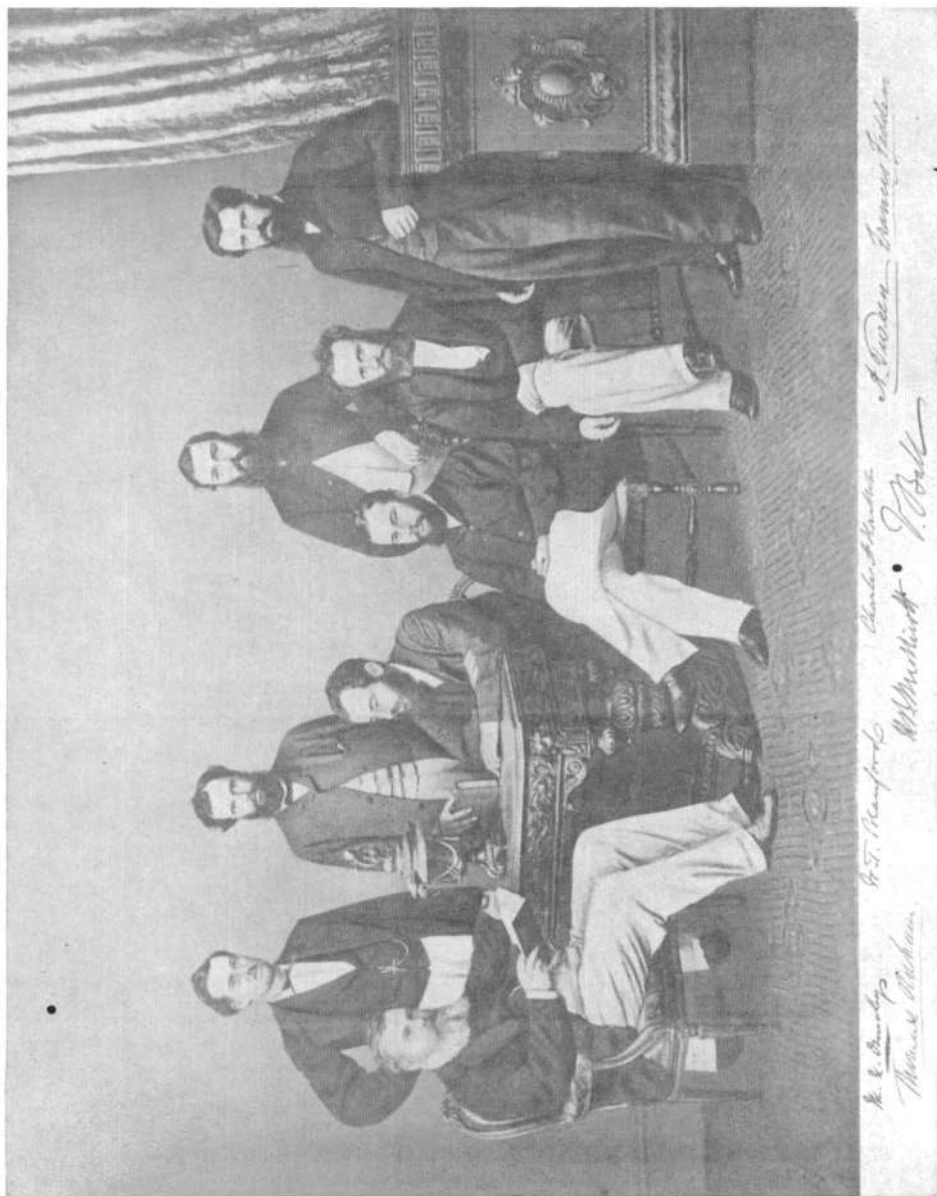
It was not however until 1852 that an attempt was made to prepare a geological map of the whole of India. This was made by G. B. Greenough, who, however, had never visited India; and it was not until 1877 that the first official map was published, on the scale of 64 miles to one inch. Though published after T. Oldham's retirement, he had been largely responsible for its preparation, and the geology shown on it summarised the results of surveys made during the first 25 years of the Geological Survey of India.

Though Voysey, Dangerfield and Herbert did have some local official status, there was no definite plan for the geological survey of the whole of India, which had not at that time entirely come within the orbit of British rule.

A high place in the history of the Geological Survey of India should be given to Dr. J. McClelland. In 1837 he was appointed as Junior Member and Secretary of the Committee for "The Investigation of the Coal and Mineral Resources of India", a committee that collected much useful information regarding the distribution of coal-bearing formations in eastern India. It was due to him that D. H. Williams was called out in 1845 from the British Geological Survey "for the purpose of making a geological survey of those districts in which coalfields are situated". Williams arrived in Calcutta on the 4th February 1846 and spent two seasons in studying the area between the Raniganj coalfield and the Kaimur plateau. He died on 15-11-1848 at Hazaribagh of fever caught while in camp, and his partially trained assistant described himself on 25-11-1848 as "in charge of the Geological Survey of India". This is probably the first time the title "Geological Survey of India" was used, even if self-styled and without official sanction. After Williams' death McClelland was anxious to bring out more trained geologists with a view to obtaining a preliminary broad picture of the distribution and relationships of the coal formations in the country, before attention was paid to the minute details of unco-ordinated seams. The East India Company, however, took the narrower view that McClelland should carry on where the detailed examination of Williams had been terminated, and on a traverse to the Barakar river he immediately discovered the Giridih coalfield, of small dimensions but containing the best coal in the country. In 1850 he asked to be relieved of his geological duties as "officiating Superintendent" of Geological Surveys, and there was an interval of 11 months before Thomas Oldham arrived in India on the 4th March 1851.

From the date of Thomas Oldham's arrival there has been an uninterrupted Geological Survey, and it is 1851 which

is now being celebrated in this Centenary. It is clear, however, that the Department developed from the earlier idea of a coal and mineral survey, and that McClelland's committee of 1837 should really be regarded as its progenitor, with Williams (1846) as a step-father. Had Williams not suddenly died in 1848, it is possible that the Department would have developed for some time along narrower lines without attempting to understand the broader geological framework. In this sense it is fortunate that the views of McClelland, and later in more concrete form of Thomas Oldham, ultimately prevailed, and that the knowledge of the distribution of geological formations and basic structures was regarded as fundamental to any sound study of the mineral resources.



<u>Wm. & Burdick</u>	W.T. Hamford	Charles H. Martin	A. Widen - Pioneer Station
Thomas M. Chapman	Wm. McKinnis	J. Bell	

THOMAS OLDHAM

1851-1876

When Thomas Oldham joined the post of Geological Surveyor as successor to Williams at the age of 35, he was already a Fellow of the Royal Society of London, Professor of Geology in Dublin and Local Director of the Geological Survey of Ireland and President of the Geological Society, Dublin. His appointment was for five years in the first instance, the term being extended by five-yearly contracts till 1876, when he retired from India at the age of nearly 60 after serving for 25 years. Following McClelland he assumed the designation Superintendent of the Geological Survey of India and was so addressed in official correspondence until his retirement.

Thomas Oldham had no permanent headquarters until 1855, when a house was fitted up as an office at 1 Hastings Street, Calcutta. Soon after his arrival in India he began field work in the Khasi hills and in the Damodar valley, areas which were either known or reported to be rich in mineral resources particularly coal.

Starting the work alone, Oldham gradually added to his department one or two officers a year until by 1855 he had on his staff: J. G. Medlicott, W. Theobald, H. B. Medlicott, W. T. Blanford and H. F. Blanford.

There were besides two other officers for a short time, R. I. St. George, and J. S. Kennedy.

Of this initial team of geologists, Oldham and the two Medlicotts came from Trinity College, Dublin, and the two Blandfords from the Royal School of Mines, London. H. B. Medlicott and the two Blandfords were admitted as Fellows of the Royal Society, London subsequently.

Oldham himself initiated the investigation of the Khasi hills and the Damodar valley; as recruitment proceeded, the Rajmahal hills, the Narbada-Satpura area, the Talchir coal-

field and large parts of Central India, were surveyed, Oldham himself either initiating the work, or visiting the parties. A party was formed in 1854 to survey the Narbada and Satpura districts, with J. G. Medlicott in charge, assisted by H. B. Medlicott and J. S. Kennedy and later by W. Theobald. At that time coal was the principal objective of search in all these areas. Oldham, however, combined with this search for coal a systematic study of the conditions under which coal-bearing rocks occurred, and so began the continuous geological survey of the country in which the coal lay.

Accompanied by Theobald, he visited the Tenasserim province and the lower part of the Irrawady valley in Burma. He then accompanied Major Phayre on his celebrated visit to the court of Ava, between the second and the third Burmese wars. In the Yenangyaung oilfield which also he visited in 1855, he is said to have been the first to recognise the connection between anticlinal structures and the collection of oil.

Early Surveys

During the coal survey, which included the portions of the Satpura range to the south of the Narbada valley, such as the Pachmarhi hills, J. G. Medlicott recognised the principal sub-divisions of the coal-bearing series, to which, in his memoir 'On the Geological Structure of the Central portion of the Narbada District', published in 1860, he applies the names Talcheer proposed by the Blandfords, Damudas and Mahadevas proposed by Oldham for the principal divisions of the coal-bearing series, and Lameta.

The two Blandfords, with the aid of Theobald, surveyed the Talchir coalfield in Orissa, during the field season of 1855-56, the results being recorded in a paper 'On the Geological Structure and Relations of the Talcheer Coalfield, in the District of Cuttack'. This memoir was thus the first systematic study of Indian geology to be published by the Geological Survey of India. The memoir contains a detailed

description of the basal beds of the coal-bearing series (now termed the Gondwana system), and a discussion of the origin thereof. By a process of elimination of the possibilities, the authors, working in one of the hottest parts of India, decided in favour of floating or ground ice as the only theory that could satisfactorily explain all the observed phenomena, typified by the presence of boulders often of large size embedded in a matrix of fine silt. They proposed the name 'Talcheer Group' for this boulder bed and certain other beds overlying it, separated by an unconformity from the higher 'Damoodah Group'. In this ascription of the formation of the Talchir beds to ice action, to be confirmed later by the discovery elsewhere of faceted and scratched pebbles, and ice-scratched pavements, one of the foundation stones had been laid for the later conception of Gondwanaland as a great southern continent.

H. B. Medlicott, in his survey in this tract in 1854-55 crossed the Singrauli coalfield, and surveyed the country on the north side of the Narbada valley, and thus laid the foundations of our knowledge of what are now called the Vindhyans. He established the three-fold division thereof, and adopting the names proposed by Oldham in 1856, namely Bundair (Bhander), Rewah and Kymore (Kaimur), he called the underlying rocks the Sub-Kymores, now known as the Lower Vindhyan. In his Memoir 'On the Vindhyan rocks, and their associates in Bundelcund', presumably incorporating some later work, he recognises also the Bijawar series, and to the equivalent of the Sub-Kymores found to the north-west he applied the names of Semri and Tirohan, etc. The Vindhyan were shown by him to be older and quite separate from the coal-bearing rocks, which helped in clearing up the confusion regarding their identification that had been caused by both being formed largely of sandstones and shales.

However unorganised the Department may have been prior to 1856, it is doubtful if so many discoveries of fundamental importance were made during any subsequent similar period.

The organisation of a proper Department

Oldham's contract was renewed for a second term of five years with effect from March 5, 1856, and he thereupon submitted his proposals for the organisation of the Department, with suggestions for :—

- (a) The systematic mapping of the whole country with special examination of areas of immediate economic interest so that in course of time a general geological map could be published, the only way to achieve sound practical results. Since during the first five years the officers had had to devote a considerable amount of their time to the preparation of topographical maps, he advocated systematic geological mapping of the country on 1" : 4 miles Atlas of India series of maps where available, and larger scale Revenue Survey maps on 1" : 1 mile scale only in limited districts.
- (b) The introduction of departmental publications; till then the papers were scattered partly in Government Records and partly in the Journal of the Asiatic Society of Bengal and elsewhere.
- (c) A central office with Library, Laboratory and Museum, without which officers had been working with the same difficulty that would confront a tradesman without his tools or a physician without medicine.
- (d) Better prospects of the Assistants for their attainments and educational qualifications, no less than for the risks of exposure to fatigue and fever. He had lost four Assistants, one by death and three by their accepting better appointments. The scale of Rs. 300/- to Rs. 600/- with an annual increment of Rs. 50/- after the first two years of probation was suggested.

- (e) The extension of the survey to Madras for which Atlas of India sheets were available, and for which three or four additional assistants were required.

Lord Canning, as Governor-General, took a strong interest in Oldham's proposals and it was due to his initiative and active support that most of Oldham's suggestions were given effect to. From 1856, till Oldham's retirement in 1876, the history of the Department was one of steady growth.

Lord Canning ordered that, except for very special circumstances, the geological survey was to be confined to those parts of the country which had already been topographically mapped, and steadily to proceed, as far as the map existed, over the country from east to west, in the manner that Oldham had advocated almost from the beginning.

Oldham's staff was increased, a museum and laboratories under a Curator provided at his office in 1856, the labours of the Survey systematized, and the reports were ordered to be published in a uniform series.

Oldham accordingly started providing annual reports on the progress of the work of the department, the report entitled "Annual Report of the Geological Survey of India, and of the Museum of Geology, Third Year, 1858-59" being that first known. The Annual Report was later merged in Part I of the Records of the Geological Survey of India, published annually since 1868.

In addition, the Memoirs of the Geological Survey were inaugurated in 1856, containing reports on different districts in one uniform series, and the *Palæontologia Indica*, containing plates illustrative of fossil remains in India, in 1861.

Oldham entered the second period with J. G. Medlicott, W. Theobald, the Blanford brothers, and with H. B. Medlicott still at Roorkee, but available for field work at intervals.

By 1860, Oldham's staff had been increased by the addition of the following : Charles Aemilius Oldham, W. K:

Loftus, Walter Lindsay Willson, J.S. Wilson, William King, J. Geoghagan, Harry Child, Robert Bruce Foote, Frederick Richmond Mallet, Ambrose Tween, Richard Trench, and Francis Fedden, making a total of twelve (one Curator of the Museum and 11 Assistants).

The full strength of the Department, namely 16 Assistants, was attained in November, 1862, including three posts of Deputy Superintendent, one Curator and one Palæontologist. In addition a Mining Specialist was appointed in 1868 temporarily.

These geologists were all on appointment termed Assistants. Two of them had been in Geological Survey employ before coming to India, namely W. L. Willson, who had been on the staff of the Geological Survey of Ireland since 1845, and R. Trench, who had been on the staff of the Geological Survey of Great Britain since 1858. William King came from Queen's College, Galway, and Child, Fedden, and Tween from the Royal School of Mines, London. Three of these Assistants died within a short time of their arrival in India; namely Geoghagan, who died of sunstroke in the Madras Presidency in April 1858; Child, who died of cholera in Calcutta in June of the same year; and Trench, who died of acute phthisis in the Upper Son Valley in May 1861.

The senior officers such as J. G. Medlicott and the two Blanfordes were placed in charge of parties, a development in organisation that was to lead to the introduction of the term Deputy Superintendent in 1862.

J. G. Medlicott and Theobald continued the survey of the Narbada district, whilst H. B. Medlicott surveyed Bundelkhand.

After the completion of the work in the coalfields of Falcher, Narbada and Satpura, systematic mapping was extended to the Archæan terrain in the Monghyr, Gaya, Bankura, Midnapore, Birbhum, Balasore, Cuttack and Puri districts by J. G. Medlicott, W. Theobald, W. L. Willson, W. T. Blanford, C. A. Oldham and H. Child. The terrain was shown to consist of crystalline schists with granite, with large

tracts under cover of alluvium and laterite. Blanford discussed the thorny questions of the composition and origin of laterite, subjects which had already exercised the minds of many writers since Buchanan-Hamilton's naming of the rock in 1807.

Coalfields Surveys

Blanford, aided at first by W. L. Willson, completed in two seasons (1858-1860) a detailed survey of the Raniganj coalfield, and published a geological map on the scale 1":1 mile, the first to be published by the Geological Survey of India on this scale, while Willson made a preliminary survey of the Karharbari coalfield.

In his discussion of the rocks of the Raniganj coalfield Blanford recognised three groups, namely Talchir, Damuda, and Panchet, the latter being a new term proposed by him and accepted by Oldham. In addition Blanford subdivides the Damudas into three sections, namely Lower Damudas, Ironstone Shales, and the Raniganj series. Oldham, in his comments on these terms pointed out the unsuitability of the term Lower Damuda and proposed the term Barakar instead. Blanford divided his Panchet series into two, namely Upper and Lower, but the name is now restricted to the lower division only, the upper division being regarded as belonging to what is now called the Upper Gondwanas. Thus arose some of the most important terms in what are now called the Gondwana system.

This Memoir also discusses in some detail the history of the development of the collieries in this field, and furnishes data which constitute a part of India's first mineral statistics printed in the Geological Survey of India publications.*

During the survey Blanford discovered vertebrate remains in the Panchets. Tween's detailed collection of the

* It will be seen from *Mém. G. S. I.*, VII, p. 131, (1869) that Oldham had in June 1859 published 'the first attempt at a careful or detailed return of the amount of coal raised in India', a return that related exclusively to the Raniganj coalfield, and that had been specially prepared as bearing on the very important question referred to Oldham regarding proposals for an extension of the then existing line of railway.

fossils, according to Huxley to whom they were sent, represented Labyrinthodont amphibia and Dicynodont reptiles. Thomas Oldham discussed the age implications of these vertebrate remains, and of the *Glossopteris* and other plant fossils found in the various members of the coal-bearing series of India, in a paper immediately following Blanford's Memoir. As a result of comparison with the known age of beds carrying similar vertebrate remains in Europe and South Africa, and similar plant fossils in Australia, Oldham allots to the Panchets an age equivalent to that of the 'earliest portion of the great Mesozoic division', or about the same age as the Bunter and Keuper of Europe. The Damudas he equates with the Permian plus a considerable portion of the Upper Carboniferous. This definite assignment of what we now know as the Lower Gondwanas to the Trias, Permian and Upper Carboniferous, was a great change from the views of the older geologists who thought that the coals of the Damodar valley were of Jurassic age.

The Mutiny of 1857 dislocated the programme of field work and Theobald narrowly missed being murdered at Mhow. J. G. Medlicott's work in Central India had to be kept in abeyance till 1860-61 when he resumed working in Rewah State. H. B. Medlicott, who was to have continued the survey from Bundelkhand to Delhi, being unable to visit these parts took up the survey of the Himalaya.

Himalayan Surveys

During 1859-61 Medlicott surveyed a large tract in the lower and outer ranges of the Himalaya and the Siwalik hills between the Ganges and the Ravi, the results of the work being published in a classic memoir. In this Medlicott laid the foundations of our knowledge of the geological structure and relations of this part of the Himalayan ranges. As a result of his survey Medlicott introduced the nomenclature of the Sub-Himalayan formations (Siwalik, Nahan and Sabathu, with its sub-divisions Kasauli, Dagshai and Sabathu) and of the

Himalayan formations (Krol, Infra-Krol, Blini (Blaini), Infra-Blini, and crystalline) and granitoid rocks, a nomenclature that with amplification is still current. The area surveyed included the Simla hills and parts of Kangra. Medlicott was much puzzled by the position in the Simla hills, e.g., on Jacko and Jutogh hill, of more highly metamorphosed rocks overlying the less metamorphosed. He was 'at first tempted to look for grand inversion of the strata'. He resisted this temptation, however, as did R. D. Oldham many years later in the same country, and as did Middlemiss in Garhwal, so that this puzzle was not solved until the present century by Pilgrim, West and Auden. The rich store of vertebrate fossils of this region was already well known from the labours, mainly between 1835 and 1845, of H. Falconer and P. T. Cautley, who were the discoverers of the Siwalik fauna, and whose fine work had been recognised by the joint presentation to them in 1837 of the Wollaston medal of the Geological Society of London. Medlicott described the Blaini 'conglomerate', later to be correlated by R. D. Oldham with the Talchirs of the Peninsula.

South Indian Surveys

Work in Southern India starting with the Nilgiri hills was begun by H. F. Blanford in 1857, with the assistance of C. A. Oldham, William King and H. Geoghagan, the two latter being newly appointed Assistants. This work was apparently done during the recess season of 1857, as it was completed by the end of the year. Blanford insisted that the rocks of the Nilgiris were not of plutonic origin but must be treated as metamorphic gneiss, the original nature of which was not in evidence, and described them as hornblendic frequently with garnets and usually devoid of mica. He was writing in the pre-microscope days of petrology, and did not know that the supposed hornblende was hypersthene, the presence of which was to lead to these gneissose rocks being later regarded as members of the charnockite series.

After the Nilgiri work, Trichinopoly and South Arcot

forming the Carnatic at the foot of the Eastern Ghats of Madras Presidency, containing Cretaceous marine fossils made known by the discoveries of C. T. Kaye of the Madras Civil Service, and Mr. Brook Cunliffe, and the descriptions thereof by Professor E. Forbes and Sir Philip Egerton, were mapped by the Madras party consisting of H. F. Blanford, C. A. Oldham, W. King, J. Geoghagan (who died from sunstroke at the end of April 1858, in the Trichinopoly district), R. Bruce Foote, and for a short while of W. T. Blanford. A considerable tract of the gneissic country to the west of the Cretaceous formation was also mapped at the same time, Blanford being specially interested in the Cretaceous and King and Foote in the older rocks of the Peninsula on which they worked for many years later. Blanford proposed the names Ootatoor (Utatur), Trichinopoly and Arrialore (Ariyalur) for the divisions of the marine Cretaceous formations of this country, now known to range from Cenomanian to Danian in age; and the term Cuddalore sandstone, now regarded as Upper Tertiary (? Pliocene) in age. During this survey Charles Oldham found fossil plants of Rajmahal age near Utatur in the Trichinopoly district, this providing the most southerly known extension in India of what we now term the Gondwana system.

Burma

The two Assistants, R. Trench and F. Fedden, who arrived in October 1860, represented an addition to the staff of two posts, to enable a geological survey of the British territories in Burma to be undertaken. W. T. Blanford was selected to commence this work, with one of the new Assistants, Fedden. The only district in the Pegu territory of which Revenue Survey Maps were then ready was Henzada, and consequently work was begun there.

Palæontologia Indica

For some time Thomas Oldham had been making preparations on his own responsibility for a new publication



Ch. OLDHAM.



WYNNE.



J. MEDLICOTT.



H. F. BLANFORD.



HUGHES.

containing plates illustrative of the organic remains of India; and he records in his Annual Report for 1860-61 (page 8) that the liberality of His Excellency the Governor General in Council had now rendered this possible. The new publication was intended to be supplementary to the *Memoirs* of the Geological Survey of India, and was entitled the *Palæontologia Indica*, destined to become so famous to palæontologists throughout the world. H. F. Blanford had the distinction of writing the first part, which appeared in 1861 as 'I. The Fossil Cephalopoda of the Cretaceous Rocks of Southern India, Belemnitidae-Nautilidae', pp. 1-40, with 25 plates. As already related H. F. Blanford left the Geological Survey in 1861 for the chair of Physics at Presidency College, Calcutta. The description of 'The Cretaceous Fauna of Southern India' was continued later by Stoliczka in successive volumes from 1865 to 1873, and Blanford's paper became Part I of Volume I of Series I.

During 1861-65 the following officers were recruited : C. A. Hacket, T. W. Hughes, Dr. H. Kane, A. B. Wynne, C. J. Wilkinson, Dr. F. Stoliczka, V. Ball, the establishment being brought to full strength of 16 Assistants in November, 1862. Of these, Kane and Wilkinson resigned for ill-health in 1864 and 1865 respectively.

In the same year, three senior posts of Deputy Superintendent were created and filled by H. B. Medlicott, in charge of Bengal and Upper Provinces (most of north India from the north-west Himalaya to Assam as well as parts of Central India and Central Provinces); W. T. Blanford, in charge of Bombay (including Sind, Kutch, Gujarat and part of Central Provinces); and C. A. Oldham, in charge of Madras (including Hyderabad and the Godavari valley). Even with these senior officers to help, Oldham paid extended visits of inspection to the field. He kept a very close watch on the work of the department and made a practice of himself examining new discoveries and advances, wherever possible. During this period the Annual Reports continued to be published with this change, however, that from 1867 the

periodical report was changed from the official year (April to March of the following year) to the calendar year.

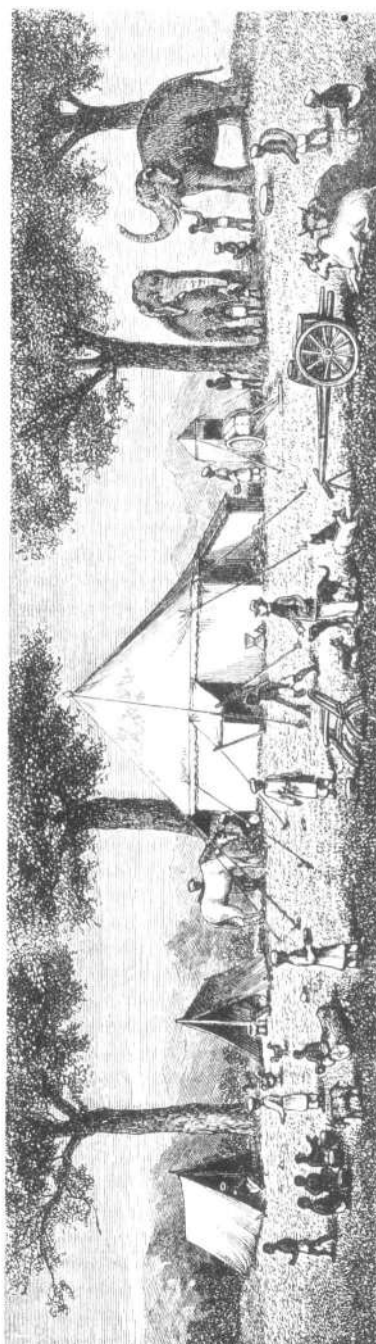
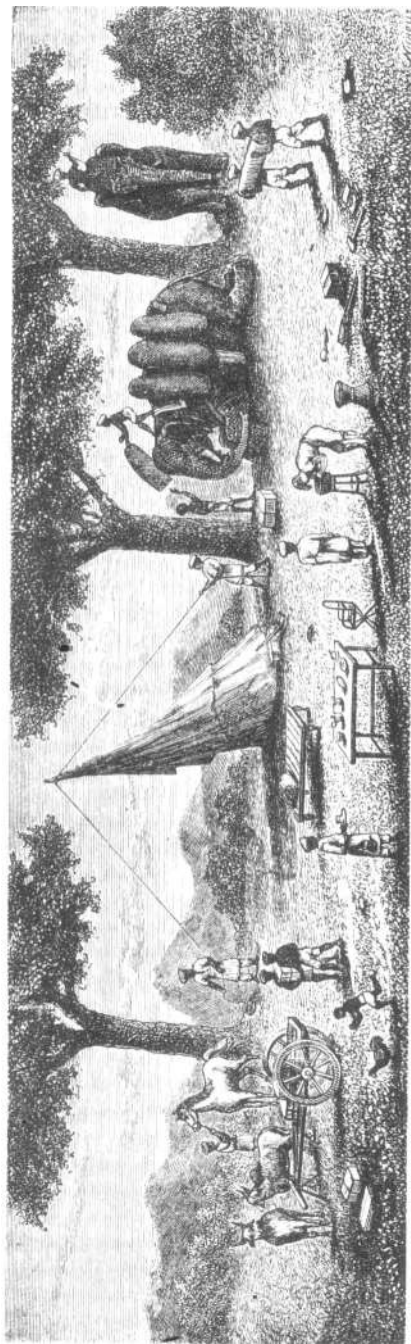
**Bengal, N. W. and N. E. India, Central India
and Central Provinces**

Hughes commenced his long series of surveys of the coalfields of India and Burma, beginning with the Jharia coalfield. By turn he surveyed the Bokaro, Ramgarh Karanpura (partly with Ball), the Palamau or Daltanganj and other coalfields.

Hughes is remembered in the department no less for his love of sports than for his excellent work. He is credited with having shot 100 tigers and 500 bears, the highest on record for any officer of the department. He used to get his information of the whereabouts of the animals and of the coal outcrops by a system of rewards to the villagers who were paid at the rate of Re. 1/- for information of a new outcrop of coal and Rs. 2/- for that of a bear.

In 1865 and 1866 after finishing his coalfield work with Hughes, Ball began his examination of the metamorphic and crystalline rocks of Manbhum and Singhbhum.

Further west, Mallet and Fedden and Hacket were at work in Central India and C. P., Rewah and the Narbada valley, along the northern edge from the Son valley to Kalinjar Fort in Banda district and along the western boundary between the crystallines and the Vindhya's from Bharatpur to Nimach, Central India and the country round Gwalior. Mallet subdivided the Vindhya's in the north-western and central portions into a number of stages introducing such terms as Sirbu, Ganugarh, Jhiri, Panna and Bejaigarh. He also recognised eleven stages in the Lower Vindhya's, proving the correctness of H. B. Medlicott's surmise in 1860 that the Sub-Kymore series of the Son valley and the Semri series of Bundelkhand are the same and belong to the Lower Vindhya's.



from "Jungle Life in India"
by V. Ball, G. S. I. (1880)

THE CAMP AT 6 A.M. AND 6 P.M.

Medlicott, who was in charge of the Bengal party, proved that the rocks of the Raipur basin did not belong to the coal-bearing series as thought by the Rev. Hislop, but to the Vindhyans. He visited the Assam valley and established the existence of valuable coal seams to the south of the Brahmaputra river, the principal fields being those of Makum and Jaipur.

The North-West Himalaya

Mallet, Theobald and Stoliczka made expeditions to the Sutlej and Spiti valleys and the higher Himalaya to collect Mesozoic and Palæozoic fossils as well as to work out the structure of these very interesting regions. The fossils collected were thought to range in age from Silurian to Cretaceous. Stoliczka's work introduced several stratigraphical names, such as 'Muth', 'Spiti', 'Kuling' and 'Lilang', etc. He also introduced the term "Central Gneiss" for what he regarded as the main geological axis of the North-West Himalaya. It is described as a porphyritic granitoid gneiss with veins of albite-granite.

In 1865, Stoliczka traversed the region from Simla to Srinagar and back, returning by a different route, in the course of six months, a feat requiring tremendous powers of endurance. The principal new discovery was that of the nummulitic beds of the Indus valley in Ladakh, which Stoliczka refers to as the Indus or Shingo beds.

Western India

Blanford pointed out the connection between the marine Bagh beds of the Narbada valley and the Lameta beds of Jubbulpore.

W. T. Blanford with Wynne and Wilkinson connected the western end of J. G. Medlicott's area in the Narbada valley with the sea at the Gulf of Cambay, the Bombay Island and Konkan, for which Oldham expressed justifiable pride and pleasure. Kutch and Sind were visited and Blanford

discovered in Kutch plant-beds of similar aspects as those of Rajmahal and Madras, the intercalated marine beds containing fossils of Jurassic age.

The Deccan trap

Working on the Deccan traps, Blanford pointed out that the rocks previously regarded as intrusive volcanic breccias were ash beds. He further noticed that the traps were horizontal and widely distributed and that they were of terrestrial origin with intertrappean beds containing fresh water fossils. He showed that they overlie the Bagh beds and are in places overlain with a marked unconformity by beds of nummulitic age and observes, "it appears highly probable that part, at least, of the traps are Upper Cretaceous in age." He suggests that the uppermost flows of Bombay and Mahabaleshwar might have been contemporaneous with the oldest Tertiaries. He also made the famous collection of zeolites which are now known all over the world. At the end of 1867, Blanford was deputed to accompany the British Military Expedition to Abyssinia as Geologist where he noted lava flows similar to those of the Deccan.

Madras

C. A. Oldham with King and Bruce Foote continued to work steadily northwards up the coastal tracts of Karnatic and the Coromandel section of the Eastern Ghats through the districts of Salem, South and North Arcot, Madras, Nellore, Cuddapah, Kurnool and Kistna. By the end of 1867 the party had completed the survey of an area of some 58,000 square miles. The metamorphic rocks were mapped and described at an age when the microscope was not in use, so that the gneisses of the Shevaroy hills and other mountain masses now known to be composed of hypersthenic rocks are referred to as hornblendic gneisses. They record the occurrences of bands of crystalline limestone in the Trichinopoly district, of magnesite veins in the Chalk hills

of Salem, and also of chromite and magnetitic iron-ores of Kanjamalai, near Salem.

Foote discovered fossiliferous beds (near Sriperimatur, south-west of Madras) in which Jurassic marine fossils were intercalated with others containing plant remains similar to those found in Kutch and in the Rajmahal hills. Similar plant beds were found by C. A. Oldham and King in the vicinity of Nellore.

Stone implements

King and Foote discovered stone implements over a wide extent of the country to the west and north of Madras city. Similar finds were later made by Ball and Theobald in other parts of India and Burma. Foote retained throughout the remainder of his service and life the interest thus aroused in stone implements, and the large and valuable collection made by him is now in the Madras Museum and is known as the Bruce Foote collection, containing 'precise similarity in form and design which exists between those found in India and those in Europe'. When discussing the stone implements of Burma, Theobald notes " . . . it would be difficult to say from shape or manufacture whether any particular implement of palæolithic type had been manufactured in Kent or Kuddapah, or if a particular neolithic belt of greenstone was from the neighbourhood of the Son or the banks of the Shannon".

Further expansion

With M. H. Ormsby recruited in 1866, Oldham's staff as it stood in 1868 was as follows :—

Deputy Superintendents :

H. B. Medlicott,	W. T. Blanford and
C. A. Oldham.	

Assistants :

W. Theobald,	W. King,
W. L. Willson,	R. B. Foote,

F. R. Mallet,
F. Fedden,
C. A. Hackett,

T. W. H. Hughes,
A. B. Wynne,
V. Ball and

M. H. Ormsby.

Curator :

A. Tween.

Palæontologist :

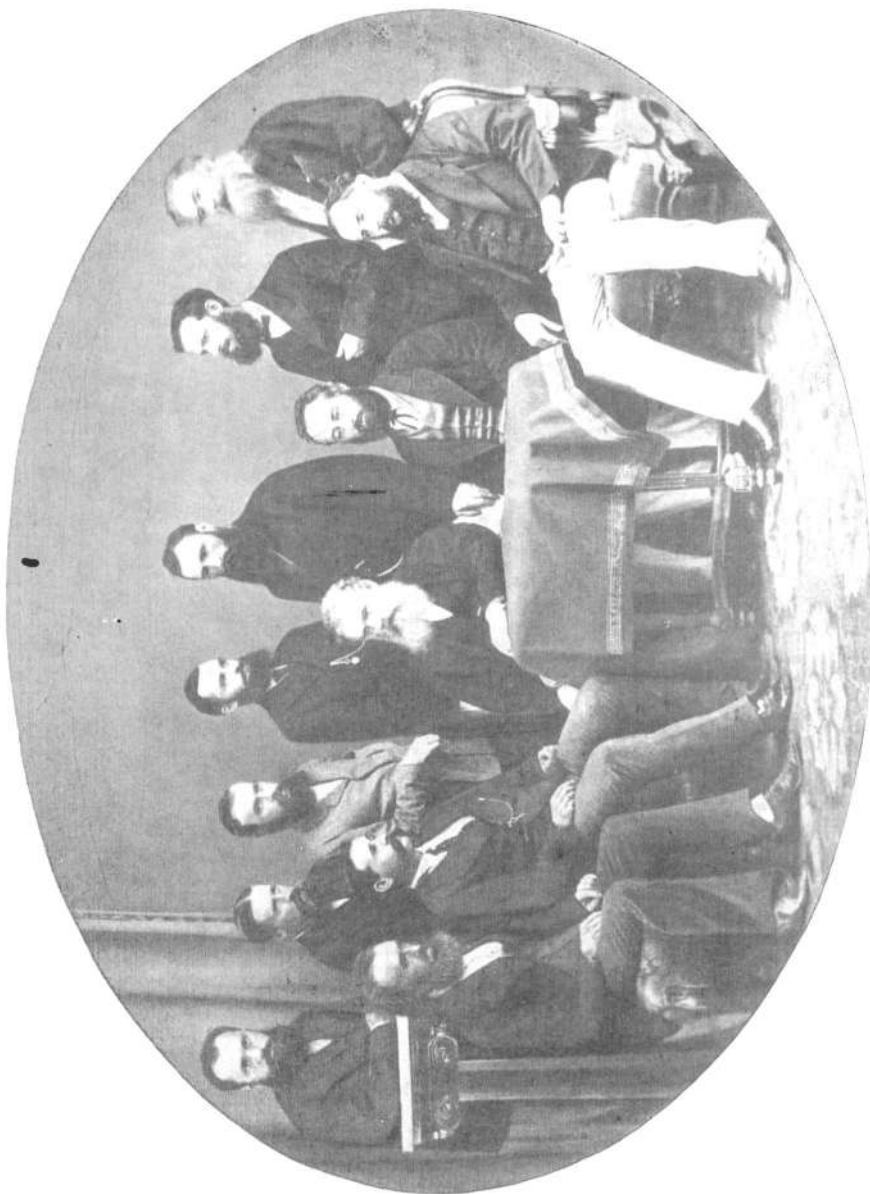
F. Stoliczka.

and the following officers were added to the staff until Oldham's retirement in 1876 to replace losses due to death and resignation : Mark Fryer (as Mining Specialist), Dr. W. Waagen, J. W. Alexander, James Willson, R. Lydekker, Dr. O. Feistmantel. The losses by death during this period were three in number, namely, Charles Oldham (1869), Ormsby (1870) and Stoliczka (1874), while J. W. Alexander and James Willson left the Department.

Among other appointments, though of a subordinate nature, mention should be made of that of Jules Schaumburg, who was appointed Chief Draughtsman to the department on the 12th April, 1869, and died on the 12th February, 1886. He will be remembered for the beautiful lithographed plates which adorn many of the Survey's publications. Mr. W. R. Bion was appointed as Librarian on the 12th December, 1870. He became Chief Clerk in 1875, and Registrar on 31st December, 1878, and died on 22nd July, 1891.

Due to Oldham's earnest endeavours an attempt was made to train Indian geologists through a system of apprenticeship, as geology was not taught in colleges in India at that time. Three students were recruited, Ram Singh in 1873 and Kishen Singh and Hira Lall in 1874. The two latter served with sufficient credit to be promoted as Sub-Assistants on the 1st April, 1879, and retired in 1903 and 1904 respectively.

Dr. Ferdinand Stoliczka on his return journey to India with a rich and valuable zoological collection from the



Standing.—F. STOLICZKA. R. B. FOOTE. W. THEOBALD. F. R. MALLET. V. BALL. W. WAAGEN. W. L. WILLSON.
Sitting.—A. TWEEN. W. KING. T. OLDHAM. H. B. MEDLICOTT. C. A. HACKET.

Yarkand Mission to Kashgar, during which he also visited the Pamir Steppe, met with death on the 19th June, 1874 at Leh. He had fallen "a sacrifice to his over-exertion in the cause of science" at an early age of 36. "He left behind him a noble monument of his research and powers in the *Palæontologia Indica* . . . in which, just before his departure for Yarkand, he had completed the description of the Cretaceous Fauna of Southern India in four large volumes".

Dr. Wilhelm Waagen, friend and associate of Stoliczka, was appointed Palæontologist on the 21st April, 1875, but owing to ill-health he was compelled to resign the service on the 24th August of the same year. Later, he became Professor of Palæontology at the University of Vienna. His principal contributions to Indian palæontology were a memoir on the Jurassic Cephalopoda of Kutch in the *Palæontologia Indica*; and after his retirement, a series of publications on the Salt range fauna.

Assam, Bengal and the Upper Provinces

Wynne and Waagen in the Punjab, Hacket and Willson in Rajputana, Hughes, Fedden and Ball (with Ormsby for a short period before his death) in Bengal and Bihar, continued their surveys, while Medlicott explored the Cretaceous coal-fields of the Garo hills, and the Shillong plateau, Khasia hills. He determined the nomenclature and sequence of the geological formations constituted by the Marine Tertiary and Cretaceous beds which bear a close affinity to the Cretaceous of Trichinopoly, and which rest unconformably on the Sylhet trap and the Shillong series held by him as equivalents respectively of the Rajmahal trap and the Dharwarians of Bihar.

Mallet examined the coalfields of the Naga hills where he established the main sub-divisions of the Tertiary sequence of Upper Assam in which coal and petroleum are found, and mapped the coal and petroleum occurrences. His main sub-divisions, the Dihings, the Tipam series, the Coal Measures

and the underlying Disang series have provided the basis of all subsequent geological work in the area.

Mallet mapped the Darjeeling district and the Bhutan Himalaya and found several coal outcrops belonging to the Damuda series and several occurrences of copper ore. The coal measures mark the northerly extension of the Gondwanaland. Besides the Tertiary beds and the Damudas, he separated the Baxa series, Daling and Darjeeling gneiss which dip into the hills and are superposed in the order named from the south to the north. He considered the Tertiaries to have been deposited at the foot of steep scarps of older rocks, the present line of junction representing the boundary of the original limit of deposition, possibly modified by subsequent faulting. This line is what was later to be regarded as the Great Boundary fault of the Himalaya. Among the older rocks, he, like Medlicott in the North-Western Himalaya, was not prepared to recognise inversion, so that he regarded the Baxas, Dalings and the Darjeeling gneiss younger than the Damudas.

Mallet continued his Son valley work into the southern parts of Mirzapur and adjoining parts of Rewa and mapped the coal occurrences of Kota in the Singrauli coalfield.

Ball continued his survey of Manbhum and Singhbhum where he made a special study of the 80-mile long copper belt, and of the Bistrampur coalfield, the Raigarh-Hingir coalfield in Gangpur, of Chotanagpur and Sirguja, the Mahanadi valley between Sambalpur and the Talchir coalfields. His Singhbhum map has been a source of information to all subsequent workers, both geologists and mining men. The crystallines were divided into two groups, Sub-Metamorphic or Transition, and Metamorphic, the former group being now regarded as corresponding largely with the Dharwarians of South India.

The Satpura Coal-basin and the Gondwana system

H. B. Medlicott devoted most of the time from 1868-69 onwards till Oldham's retirement to problems connected with

the coalfields, particularly those of the Satpura, Mohpani and Shahpur (Betul). His conclusions on the Satpura basin coincided with those of Hughes with regard to the Bengal coalfield, that the present limits of the coal measure rocks coincide approximately with the original limits of deposition and are not the results of faulting or of denudation. With regard to the coal-bearing rock systems, the most important nomenclature proposed by him was the Gondwana system, after the ancient Gond Kingdom, which extended from Chanda into the Satpuras.

On more detailed maps being published, Medicott started the revision of the geological maps of Central India and the Central Provinces, the Deccan trap, the Bundelkhand gneiss and the Bijawars in 1870.

Hackett's work lay mainly in the Jubbulpore district and in the adjoining area of Gwalior, where he introduced the term Gwalior series, and westwards into the Aravalli region in Rajputana, where he introduced the term Aravali series for the rocks largely composing the Aravalli range. He later introduced the term Delhi series for what he thought to be the younger members of his original Arvalis. He still retained the term Arvali series for the rocks constituting the high hills of the Aravalli range. The later work of Middlemiss and Heron has however proved these to be highly metamorphosed members of the Delhis.

The Salt Range, Attock and the Trans-Indus Salt region of Kohat

Wynne, who was assisted by Waagen in the palæontological work, separated 15 groups of strata in the Salt range ranging from post-Tertiary down to his 'Obolus beds' (regarded as Silurian at the time) and to the underlying Purple sandstone and the basal Saline series. Although subsequent palæontological studies by Waagen and Warth have modified the ages ascribed by Wynne to some of his groups, his work securely laid the foundations of our knowledge of the

stratigraphy of this part of India; and his conclusion that the Purple sandstone and the Saline series below it, rest with a normal superpositional contact beneath his *Obolus* beds, according to the latest stratigraphical work of Gee, still stands valid.

Kutch

Wynne and Fedden investigated respectively the marine Jurassics associated with plant beds which were divided into two groups, and the Tertiaries, of Kutch. Stoliczka visited Kutch later and established the now familiar sub-divisions of the Jurassic, Patcham, Chari, Katrol, and Umia, the last ranging into the Lower Cretaceous. The Cephalopods of Kutch were described by Waagen, but the remainder of the rich collection made by Wynne, Fedden and Stoliczka were not described until recently.

Dr. Feistmantel, who joined in 1875, took up the description of the fossil floras of the Gondwana system in the *Palæontologia Indica*, his first contribution being on the Jurassic (oolitic) Flora of Kach. He pointed out that there was a palæontological contradiction between the evidence of the animal and the plant remains: the plants indicating a somewhat greater age than the animals.

The Wardha Valley Coalfield

Mark Fryer, specially appointed Mining Specialist, conducted boring operations in the Chanda district during 1868-69, with Oldham himself coming to the C. P. to control the operation. Hughes who commenced surveying in this region from 1869-70 continued until 1873, controlling the operations afterwards. He grouped several areas of coal-bearing rocks, which he separated from the Upper Gondwanas of the Wardha valley, under the new term Kota-Maleri.

The Kota beds contained fossil fish discovered by A. M. Walker in 1850 and T. L. Bell in 1851, and plants discovered by Hughes and King; whilst the Maleri beds contained fish

teeth and reptilian bones discovered by the Rev. Stephen Hislop in 1859, and were older than the Kota stage. Besides the Gondwana tract, he mapped a large portion of this part of India with Fedden, and showed it to be composed of Vindhya's (King later separated the lower portion as Cuddapahs), Gondwanas, Deccan trap, Lamets and Metamorphics. He estimated 2,000 million tons of coal, of which only a portion could be regarded as available, while Tween's analyses showed that whilst much of it was of fair quality it was non-coking.

The Sind Tertiaries

Blanford's and Fedden's researches in Sind during 1874-76 showed that the Tertiaries there ranged in age from Lower Eocene to Pliocene, and to the various divisions recognised ranging from Infra-Nummulitic to Supra-Nummulitic and Siwalik Blanford allotted the now well-known names Ranikot, Laki, Khirthar, Nari, Gaj and Manchar, the later being regarded as equivalent to the Siwaliks. The completed survey of the region which took a year longer, showed the existence beneath the Ranikot stage of rocks regarded as Cretaceous, consisting of *hippurite* limestone overlain by *Cradita beaumonti* beds (Upper Cretaceous-Eocene). Their discovery of two lava flows (correlated with the Deccan trap flows) between the *Cradita beaumonti* horizon and the Ranikot beds, and a third one interstratified in the sandstone underlying the *Cradita beaumonti* beds threw light on the time period of the lava flows in this region which has a bearing on the question of the age of the flows—a subject of much controversy lately

The Madras Party

The work of C. A. Oldham, King and Foote during the period led to the mapping of the Cuddapah and Karnool basins, and their subdivision into stages, and the discovery of the Upper Gondwanas of Guntur and Ongole. On C. A. Oldham's death in 1868, King was appointed Deputy Superintendent for

Madras and he continued with Foote the mapping of the Southern Mahratta country and adjacent districts. Foote recognised two principal elements in the gneissic rocks, *viz.*, of granitoid and schistose nature, arranged in great bands traceable for miles with a general N. N. W.-S. S. E. strike. The schist bands he was later (1886) to separate from the gneissic complex as Dharwars.

Burma

Theobald's work in Burma from 1867 to 1872-73 laid the foundations of our knowledge of the geology of Burma from Cape Negrais up to latitude $19^{\circ}30'$ North. Of the terms proposed by him to designate his Burmese formations, the well-known ones are Fossil-wood group, Pegu group, Negrais group and Axial group. He also gave an account of the petroleum occurrences and of brine springs.

Oldham introduced the practice of sending officers of the department with trans-frontier and overseas expeditions, e.g., W. T. Blanford in Abyssinia (1867-68) and Persia (1871-72), Stoliczka with the Yarkand Mission (1873-74) and himself with Phayre's Mission to the court of Ava in 1855. In the course of such work on the Baluchistan-Persian frontier, W. T. Blanford proposed the name of Makran for the younger marine Tertiary beds along the Makran coast of Baluchistan, and also the Hormuz salt formation of the underlying beds of the Hormuz Island.

Economic Geology

A large proportion of the work was directed to the coalfields and special Memoirs were written on the subject. In addition, iron-ores, limestones and building stones, the salt deposits of the Punjab, the oil springs of Assam, the Punjab and Burma, and numerous minor occurrences of a great variety of other minerals were described in the Memoirs of the surveyed areas. The copper deposits of Dhalbhum and Singbhum and of the auriferous rocks of the Dambal hills.

Dharwar district, and gold in the Wynaad may also be mentioned in this connection.

Next to coal, the most important problem was the possibility of producing the iron needed for the construction of railways. Iron works were established in Kumaon from 1857-60, using local iron-ores and wood as fuel. Although in the Department's opinion the Raniganj coalfield area was the most promising place for a trial, a specialist was sent out from England by the Secretary of State for India to give a definite opinion on the feasibility of establishing iron works in India. The specialist, Mr. Hilary Banerman, who was accompanied by Mr. Ball, reported unfavourably on the Kumaon venture. The local authorities were not satisfied; so Mr. T. W. H. Hughes was deputed to make a further report which was also adverse. Nevertheless, the Government did again embark on the manufacture of iron in Kumaon from 1877-79, despite the emphatic language, evoked by hurt feelings, with which Mr. Medlicott commented on Banerman's visit, in the Annual Report for 1874. To quote Medlicott:—

“Even if Mr. Banerman's deputation to India had not so directly touched upon the work of the Geological Survey, it would call for notice here. He is the latest of a series of experts . . . Mr. Banerman has simply re-stated the case in a more intelligible form than some of his predecessors, but no more than it has all along been expressed by the Geological Survey . . . that under the existing circumstances, the Raniganj coalfield is the most promising place for a trial . . .”

Oldham also initiated the study of earthquakes in India, himself taking the field in 1869 after the Cachar earthquake. He prepared the first catalogue of Indian earthquakes. He also prepared the first list of thermal springs in India and listed 301 springs.

With the aid of his staff, a large proportion of India was surveyed geologically and the compilation of the first authentic geological map of India was commenced in his time to be ultimately published in the year following his retirement.

The Indian Museum

In 1835, the Government of India, encouraged by the opening up of the Raniganj coalfield, decided to found a Museum of Economic Geology. This was effected in 1840, and the collections were housed with the Asiatic Society, until 1856, by which time the house newly acquired at 1, Hastings Street for the Geological Survey had been adapted for Museum purposes. The collection was then moved to Hastings Street and the Geological Museum was opened to the public on 1st January, 1857.* These changes were a part of the re-organisation of the Geological Survey of 1856 for which Oldham was responsible, and from 1856 Oldham used the dual title of Superintendent of the Geological Survey of India and of the Museum of Geology, Calcutta, a designation which was altered in his Annual Report for the year 1863-64 to Superintendent, Geological Survey of India and Director of the Museum of Geology, Calcutta.

In 1856 the Asiatic Society had moved the Government for the foundation of a public Museum in Calcutta to house its collections. In May, 1862, Government announced its intention to consider the matter, and after protracted negotiations lasting until the middle of 1865, it was provided that the Society should be given suitable and exclusive accommodation in the Museum besides retaining its house at 1, Park Street, and legislative sanction was given to the conditions in the Indian Museum Act (No. XVII) of 1866.

By the time the Museum was constructed, the collections had grown, and the Board of Trustees were of opinion that the whole accommodation would be ultimately required for Museum purposes by the Geological Survey and the Natural History Museum, but the Asiatic Society felt that their position as an independent body would be injured if housed with these two large establishments. The Government thereupon referred the matter to a Committee consisting of 'one of the most sagacious administrators and one of the acutest scientists of

* Only some 5½ years after the opening of the Museum of Practical Geology at Jermyn Street in London (12th May, 1851).

the country, Sir Ashley Eden and Dr. Thomas Oldham'. Upon their joint recommendation, the Government of India paid to the Asiatic Society Rs. 1,50,000 as compensation for its claim to accommodation in the Museum buildings. This arrangement has proved highly beneficial both to the Society and to the Museum.

It was not till 1875 that the Museum building became ready for occupation, when the Geological Survey moved into new quarters, although the transfer of specimens of the Geological Survey from 1, Hastings Street probably started in 1874. The old quarters in 1, Hastings Street were vacated on 30th September, 1875, and the new geological galleries were thrown open to the public on the 1st January, 1877, with the specimens of the Asiatic Society amalgamated with those of the Geological Survey. The Asiatic Society specimens included a valuable, though small, collection of Siwalik vertebrates.

Union of two lineages

From the facts related above it is interesting to reflect that with the re-organisation of the Geological Survey of India in 1856 two lineages were combined: that which dated from the arrival of Williams in 1846 as Geological Surveyor to the East India Company and, after a break, was continued with Oldham's arrival in 1851 to burgeon into the Geological Survey of India; and the second lineage, starting with the foundation of the Museum of Geology by the Government of India in Calcutta in 1840, housed in the rooms of the Asiatic Society of Bengal, so that the Museum section of the department has a more ancient origin than the Survey section.

THOMAS OLDHAM

1851-1876

When Thomas Oldham joined the post of Geological Surveyor as successor to Williams at the age of 35, he was already a Fellow of the Royal Society of London, Professor of Geology in Dublin and Local Director of the Geological Survey of Ireland and President of the Geological Society, Dublin. His appointment was for five years in the first instance, the term being extended by five-yearly contracts till 1876, when he retired from India at the age of nearly 60 after serving for 25 years. Following McClelland he assumed the designation Superintendent of the Geological Survey of India and was so addressed in official correspondence until his retirement.

Thomas Oldham had no permanent headquarters until 1855, when a house was fitted up as an office at 1 Hastings Street, Calcutta. Soon after his arrival in India he began field work in the Khasi hills and in the Damodar valley, areas which were either known or reported to be rich in mineral resources particularly coal.

Starting the work alone, Oldham gradually added to his department one or two officers a year until by 1855 he had on his staff: J. G. Medlicott, W. Theobald, H. B. Medlicott, W. T. Blanford and H. F. Blanford.

There were besides two other officers for a short time, R. I. St. George, and J. S. Kennedy.

Of this initial team of geologists, Oldham and the two Medlicotts came from Trinity College, Dublin, and the two Blandfords from the Royal School of Mines, London. H. B. Medlicott and the two Blandfords were admitted as Fellows of the Royal Society, London subsequently.

Oldham himself initiated the investigation of the Khasi hills and the Damodar valley; as recruitment proceeded, the Rajmahal hills, the Narbada-Satpura area, the Talchir coal-

field and large parts of Central India, were surveyed, Oldham himself either initiating the work, or visiting the parties. A party was formed in 1854 to survey the Narbada and Satpura districts, with J. G. Medlicott in charge, assisted by H. B. Medlicott and J. S. Kennedy and later by W. Theobald. At that time coal was the principal objective of search in all these areas. Oldham, however, combined with this search for coal a systematic study of the conditions under which coal-bearing rocks occurred, and so began the continuous geological survey of the country in which the coal lay.

Accompanied by Theobald, he visited the Tenasserim province and the lower part of the Irrawady valley in Burma. He then accompanied Major Phayre on his celebrated visit to the court of Ava, between the second and the third Burmese wars. In the Yenangyaung oilfield which also he visited in 1855, he is said to have been the first to recognise the connection between anticlinal structures and the collection of oil.

Early Surveys

During the coal survey, which included the portions of the Satpura range to the south of the Narbada valley, such as the Pachmarhi hills, J. G. Medlicott recognised the principal sub-divisions of the coal-bearing series, to which, in his memoir 'On the Geological Structure of the Central portion of the Narbada District', published in 1860, he applies the names Talcheer proposed by the Blandfords, Damudas and Mahadevas proposed by Oldham for the principal divisions of the coal-bearing series, and Lameta.

The two Blandfords, with the aid of Theobald, surveyed the Talchir coalfield in Orissa, during the field season of 1855-56, the results being recorded in a paper 'On the Geological Structure and Relations of the Talcheer Coalfield, in the District of Cuttack'. This memoir was thus the first systematic study of Indian geology to be published by the Geological Survey of India. The memoir contains a detailed

description of the basal beds of the coal-bearing series (now termed the Gondwana system), and a discussion of the origin thereof. By a process of elimination of the possibilities, the authors, working in one of the hottest parts of India, decided in favour of floating or ground ice as the only theory that could satisfactorily explain all the observed phenomena, typified by the presence of boulders often of large size embedded in a matrix of fine silt. They proposed the name 'Talcheer Group' for this boulder bed and certain other beds overlying it, separated by an unconformity from the higher 'Damoodah Group'. In this ascription of the formation of the Talchir beds to ice action, to be confirmed later by the discovery elsewhere of faceted and scratched pebbles, and ice-scratched pavements, one of the foundation stones had been laid for the later conception of Gondwanaland as a great southern continent.

H. B. Medlicott, in his survey in this tract in 1854-55 crossed the Singrauli coalfield, and surveyed the country on the north side of the Narbada valley, and thus laid the foundations of our knowledge of what are now called the Vindhyans. He established the three-fold division thereof, and adopting the names proposed by Oldham in 1856, namely Bundair (Bhander), Rewah and Kymore (Kaimur), he called the underlying rocks the Sub-Kymores, now known as the Lower Vindhyan. In his Memoir 'On the Vindhyan rocks, and their associates in Bundelcund', presumably incorporating some later work, he recognises also the Bijawar series, and to the equivalent of the Sub-Kymores found to the north-west he applied the names of Semri and Tirohan, etc. The Vindhyan were shown by him to be older and quite separate from the coal-bearing rocks, which helped in clearing up the confusion regarding their identification that had been caused by both being formed largely of sandstones and shales.

However unorganised the Department may have been prior to 1856, it is doubtful if so many discoveries of fundamental importance were made during any subsequent similar period.

The organisation of a proper Department

Oldham's contract was renewed for a second term of five years with effect from March 5, 1856, and he thereupon submitted his proposals for the organisation of the Department, with suggestions for :—

- (a) The systematic mapping of the whole country with special examination of areas of immediate economic interest so that in course of time a general geological map could be published, the only way to achieve sound practical results. Since during the first five years the officers had had to devote a considerable amount of their time to the preparation of topographical maps, he advocated systematic geological mapping of the country on 1" : 4 miles Atlas of India series of maps where available, and larger scale Revenue Survey maps on 1" : 1 mile scale only in limited districts.
- (b) The introduction of departmental publications; till then the papers were scattered partly in Government Records and partly in the Journal of the Asiatic Society of Bengal and elsewhere.
- (c) A central office with Library, Laboratory and Museum, without which officers had been working with the same difficulty that would confront a tradesman without his tools or a physician without medicine.
- (d) Better prospects of the Assistants for their attainments and educational qualifications, no less than for the risks of exposure to fatigue and fever. He had lost four Assistants, one by death and three by their accepting better appointments. The scale of Rs. 300/- to Rs. 600/- with an annual increment of Rs. 50/- after the first two years of probation was suggested.

- (e) The extension of the survey to Madras for which Atlas of India sheets were available, and for which three or four additional assistants were required.

Lord Canning, as Governor-General, took a strong interest in Oldham's proposals and it was due to his initiative and active support that most of Oldham's suggestions were given effect to. From 1856, till Oldham's retirement in 1876, the history of the Department was one of steady growth.

Lord Canning ordered that, except for very special circumstances, the geological survey was to be confined to those parts of the country which had already been topographically mapped, and steadily to proceed, as far as the map existed, over the country from east to west, in the manner that Oldham had advocated almost from the beginning.

Oldham's staff was increased, a museum and laboratories under a Curator provided at his office in 1856, the labours of the Survey systematized, and the reports were ordered to be published in a uniform series.

Oldham accordingly started providing annual reports on the progress of the work of the department, the report entitled "Annual Report of the Geological Survey of India, and of the Museum of Geology, Third Year, 1858-59" being that first known. The Annual Report was later merged in Part I of the Records of the Geological Survey of India, published annually since 1868.

In addition, the Memoirs of the Geological Survey were inaugurated in 1856, containing reports on different districts in one uniform series, and the *Palæontologia Indica*, containing plates illustrative of fossil remains in India, in 1861.

Oldham entered the second period with J. G. Medlicott, W. Theobald, the Blanford brothers, and with H. B. Medlicott still at Roorkee, but available for field work at intervals.

By 1860, Oldham's staff had been increased by the addition of the following : Charles Aemilius Oldham, W. K:

Loftus, Walter Lindsay Willson, J.S. Wilson, William King, J. Geoghagan, Harry Child, Robert Bruce Foote, Frederick Richmond Mallet, Ambrose Tween, Richard Trench, and Francis Fedden, making a total of twelve (one Curator of the Museum and 11 Assistants).

The full strength of the Department, namely 16 Assistants, was attained in November, 1862, including three posts of Deputy Superintendent, one Curator and one Palæontologist. In addition a Mining Specialist was appointed in 1868 temporarily.

These geologists were all on appointment termed Assistants. Two of them had been in Geological Survey employ before coming to India, namely W. L. Willson, who had been on the staff of the Geological Survey of Ireland since 1845, and R. Trench, who had been on the staff of the Geological Survey of Great Britain since 1858. William King came from Queen's College, Galway, and Child, Fedden, and Tween from the Royal School of Mines, London. Three of these Assistants died within a short time of their arrival in India; namely Geoghagan, who died of sunstroke in the Madras Presidency in April 1858; Child, who died of cholera in Calcutta in June of the same year; and Trench, who died of acute phthisis in the Upper Son Valley in May 1861.

The senior officers such as J. G. Medlicott and the two Blanfordes were placed in charge of parties, a development in organisation that was to lead to the introduction of the term Deputy Superintendent on 1862.

J. G. Medlicott and Theobald continued the survey of the Narbada district, whilst H. B. Medlicott surveyed Bundelkhand.

After the completion of the work in the coalfields of Falcher, Narbada and Satpura, systematic mapping was extended to the Archæan terrain in the Monghyr, Gaya, Bankura, Midnapore, Birbhum, Balasore, Cuttack and Puri districts by J. G. Medlicott, W. Theobald, W. L. Willson, W. T. Blanford, C. A. Oldham and H. Child. The terrain was shown to consist of crystalline schists with granite, with large

tracts under cover of alluvium and laterite. Blanford discussed the thorny questions of the composition and origin of laterite, subjects which had already exercised the minds of many writers since Buchanan-Hamilton's naming of the rock in 1807.

Coalfields Surveys

Blanford, aided at first by W. L. Willson, completed in two seasons (1858-1860) a detailed survey of the Raniganj coalfield, and published a geological map on the scale 1":1 mile, the first to be published by the Geological Survey of India on this scale, while Willson made a preliminary survey of the Karharbari coalfield.

In his discussion of the rocks of the Raniganj coalfield Blanford recognised three groups, namely Talchir, Damuda, and Panchet, the latter being a new term proposed by him and accepted by Oldham. In addition Blanford subdivides the Damudas into three sections, namely Lower Damudas, Ironstone Shales, and the Raniganj series. Oldham, in his comments on these terms pointed out the unsuitability of the term Lower Damuda and proposed the term Barakar instead. Blanford divided his Panchet series into two, namely Upper and Lower, but the name is now restricted to the lower division only, the upper division being regarded as belonging to what is now called the Upper Gondwanas. Thus arose some of the most important terms in what are now called the Gondwana system.

This Memoir also discusses in some detail the history of the development of the collieries in this field, and furnishes data which constitute a part of India's first mineral statistics printed in the Geological Survey of India publications.*

During the survey Blanford discovered vertebrate remains in the Panchets. Tween's detailed collection of the

* It will be seen from *Mém. G. S. I.*, VII, p. 131, (1869) that Oldham had in June 1859 published 'the first attempt at a careful or detailed return of the amount of coal raised in India', a return that related exclusively to the Raniganj coalfield, and that had been specially prepared as bearing on the very important question referred to Oldham regarding proposals for an extension of the then existing line of railway.

fossils, according to Huxley to whom they were sent, represented Labyrinthodont amphibia and Dicynodont reptiles. Thomas Oldham discussed the age implications of these vertebrate remains, and of the *Glossopteris* and other plant fossils found in the various members of the coal-bearing series of India, in a paper immediately following Blanford's Memoir. As a result of comparison with the known age of beds carrying similar vertebrate remains in Europe and South Africa, and similar plant fossils in Australia, Oldham allots to the Panchets an age equivalent to that of the 'earliest portion of the great Mesozoic division', or about the same age as the Bunter and Keuper of Europe. The Damudas he equates with the Permian plus a considerable portion of the Upper Carboniferous. This definite assignment of what we now know as the Lower Gondwanas to the Trias, Permian and Upper Carboniferous, was a great change from the views of the older geologists who thought that the coals of the Damodar valley were of Jurassic age.

The Mutiny of 1857 dislocated the programme of field work and Theobald narrowly missed being murdered at Mhow. J. G. Medlicott's work in Central India had to be kept in abeyance till 1860-61 when he resumed working in Rewah State. H. B. Medlicott, who was to have continued the survey from Bundelkhand to Delhi, being unable to visit these parts took up the survey of the Himalaya.

Himalayan Surveys

During 1859-61 Medlicott surveyed a large tract in the lower and outer ranges of the Himalaya and the Siwalik hills between the Ganges and the Ravi, the results of the work being published in a classic memoir. In this Medlicott laid the foundations of our knowledge of the geological structure and relations of this part of the Himalayan ranges. As a result of his survey Medlicott introduced the nomenclature of the Sub-Himalayan formations (Siwalik, Nahan and Sabathu, with its sub-divisions Kasauli, Dagshai and Sabathu) and of the

Himalayan formations (Krol, Infra-Krol, Blini (Blaini), Infra-Blini, and crystalline) and granitoid rocks, a nomenclature that with amplification is still current. The area surveyed included the Simla hills and parts of Kangra. Medlicott was much puzzled by the position in the Simla hills, e.g., on Jacko and Jutogh hill, of more highly metamorphosed rocks overlying the less metamorphosed. He was 'at first tempted to look for grand inversion of the strata'. He resisted this temptation, however, as did R. D. Oldham many years later in the same country, and as did Middlemiss in Garhwal, so that this puzzle was not solved until the present century by Pilgrim, West and Auden. The rich store of vertebrate fossils of this region was already well known from the labours, mainly between 1835 and 1845, of H. Falconer and P. T. Cautley, who were the discoverers of the Siwalik fauna, and whose fine work had been recognised by the joint presentation to them in 1837 of the Wollaston medal of the Geological Society of London. Medlicott described the Blaini 'conglomerate', later to be correlated by R. D. Oldham with the Talchirs of the Peninsula.

South Indian Surveys

Work in Southern India starting with the Nilgiri hills was begun by H. F. Blanford in 1857, with the assistance of C. A. Oldham, William King and H. Geoghagan, the two latter being newly appointed Assistants. This work was apparently done during the recess season of 1857, as it was completed by the end of the year. Blanford insisted that the rocks of the Nilgiris were not of plutonic origin but must be treated as metamorphic gneiss, the original nature of which was not in evidence, and described them as hornblendic frequently with garnets and usually devoid of mica. He was writing in the pre-microscope days of petrology, and did not know that the supposed hornblende was hypersthene, the presence of which was to lead to these gneissose rocks being later regarded as members of the charnockite series.

After the Nilgiri work, Trichinopoly and South Arcot

forming the Carnatic at the foot of the Eastern Ghats of Madras Presidency, containing Cretaceous marine fossils made known by the discoveries of C. T. Kaye of the Madras Civil Service, and Mr. Brook Cunliffe, and the descriptions thereof by Professor E. Forbes and Sir Philip Egerton, were mapped by the Madras party consisting of H. F. Blanford, C. A. Oldham, W. King, J. Geoghagan (who died from sunstroke at the end of April 1858, in the Trichinopoly district), R. Bruce Foote, and for a short while of W. T. Blanford. A considerable tract of the gneissic country to the west of the Cretaceous formation was also mapped at the same time, Blanford being specially interested in the Cretaceous and King and Foote in the older rocks of the Peninsula on which they worked for many years later. Blanford proposed the names Ootatoor (Utatur), Trichinopoly and Arrialoore (Ariyalur) for the divisions of the marine Cretaceous formations of this country, now known to range from Cenomanian to Danian in age; and the term Cuddalore sandstone, now regarded as Upper Tertiary (? Pliocene) in age. During this survey Charles Oldham found fossil plants of Rajmahal age near Utatur in the Trichinopoly district, this providing the most southerly known extension in India of what we now term the Gondwana system.

Burma

The two Assistants, R. Trench and F. Fedden, who arrived in October 1860, represented an addition to the staff of two posts, to enable a geological survey of the British territories in Burma to be undertaken. W. T. Blanford was selected to commence this work, with one of the new Assistants, Fedden. The only district in the Pegu territory of which Revenue Survey Maps were then ready was Henzada, and consequently work was begun there.

Palæontologia Indica

For some time Thomas Oldham had been making preparations on his own responsibility for a new publication



Ch. OLDHAM.



WYNNE.



J. MEDLICOTT.



H. F. BLANFORD.



HUGHES.

containing plates illustrative of the organic remains of India; and he records in his Annual Report for 1860-61 (page 8) that the liberality of His Excellency the Governor General in Council had now rendered this possible. The new publication was intended to be supplementary to the *Memoirs* of the Geological Survey of India, and was entitled the *Palæontologia Indica*, destined to become so famous to palæontologists throughout the world. H. F. Blanford had the distinction of writing the first part, which appeared in 1861 as 'I. The Fossil Cephalopoda of the Cretaceous Rocks of Southern India, Belemnitidae-Nautilidae', pp. 1-40, with 25 plates. As already related H. F. Blanford left the Geological Survey in 1861 for the chair of Physics at Presidency College, Calcutta. The description of 'The Cretaceous Fauna of Southern India' was continued later by Stoliczka in successive volumes from 1865 to 1873, and Blanford's paper became Part I of Volume I of Series I.

During 1861-65 the following officers were recruited : C. A. Hacket, T. W. Hughes, Dr. H. Kane, A. B. Wynne, C. J. Wilkinson, Dr. F. Stoliczka, V. Ball, the establishment being brought to full strength of 16 Assistants in November, 1862. Of these, Kane and Wilkinson resigned for ill-health in 1864 and 1865 respectively.

In the same year, three senior posts of Deputy Superintendent were created and filled by H. B. Medlicott, in charge of Bengal and Upper Provinces (most of north India from the north-west Himalaya to Assam as well as parts of Central India and Central Provinces); W. T. Blanford, in charge of Bombay (including Sind, Kutch, Gujarat and part of Central Provinces); and C. A. Oldham, in charge of Madras (including Hyderabad and the Godavari valley). Even with these senior officers to help, Oldham paid extended visits of inspection to the field. He kept a very close watch on the work of the department and made a practice of himself examining new discoveries and advances, wherever possible. During this period the Annual Reports continued to be published with this change, however, that from 1867 the

periodical report was changed from the official year (April to March of the following year) to the calendar year.

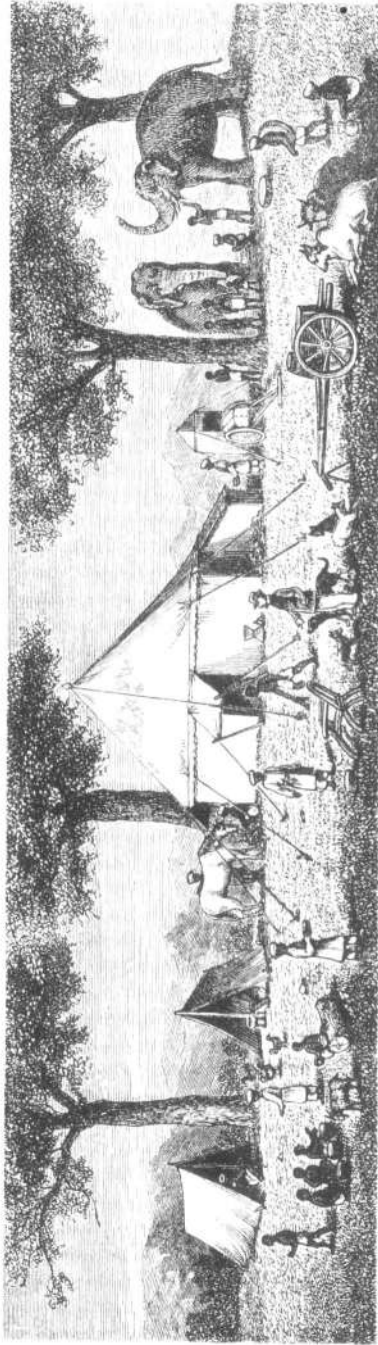
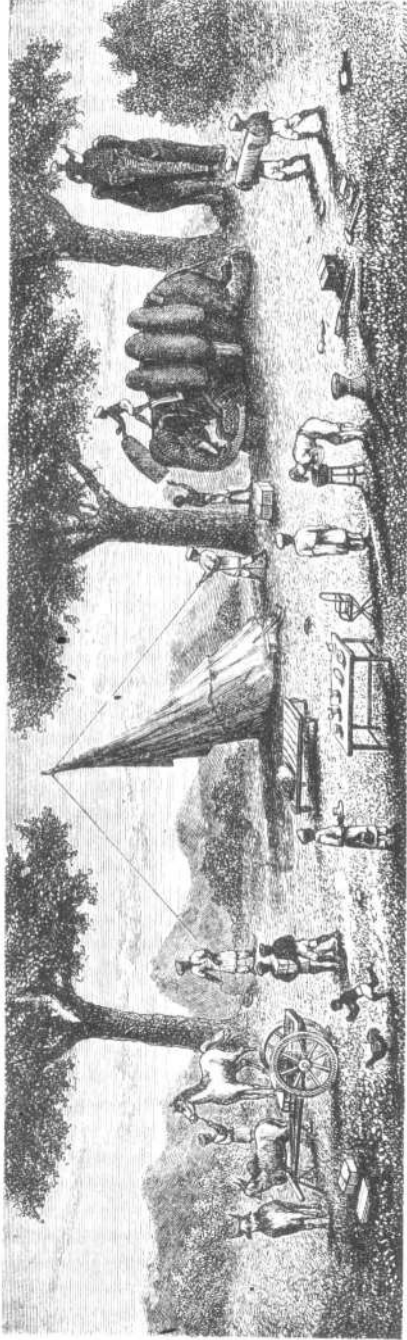
**Bengal, N. W. and N. E. India, Central India
and Central Provinces**

Hughes commenced his long series of surveys of the coalfields of India and Burma, beginning with the Jharia coalfield. By turn he surveyed the Bokaro, Ramgarh Karanpura (partly with Ball), the Palamau or Daltanganj and other coalfields.

Hughes is remembered in the department no less for his love of sports than for his excellent work. He is credited with having shot 100 tigers and 500 bears, the highest on record for any officer of the department. He used to get his information of the whereabouts of the animals and of the coal outcrops by a system of rewards to the villagers who were paid at the rate of Re. 1/- for information of a new outcrop of coal and Rs. 2/- for that of a bear.

In 1865 and 1866 after finishing his coalfield work with Hughes, Ball began his examination of the metamorphic and crystalline rocks of Manbhum and Singhbhum.

Further west, Mallet and Fedden and Hacket were at work in Central India and C. P., Rewah and the Narbada valley, along the northern edge from the Son valley to Kalinjar Fort in Banda district and along the western boundary between the crystallines and the Vindhya's from Bharatpur to Nimach, Central India and the country round Gwalior. Mallet subdivided the Vindhya's in the north-western and central portions into a number of stages introducing such terms as Sirbu, Ganugarh, Jhiri, Panna and Bejaigarh. He also recognised eleven stages in the Lower Vindhya's, proving the correctness of H. B. Medlicott's surmise in 1860 that the Sub-Kymore series of the Son valley and the Semri series of Bundelkhand are the same and belong to the Lower Vindhya's.



from "Jungle Life in India"
by V. Ball, G. S. I. (1880)

THE CAMP AT 6 A.M. AND 6 P.M.

Medlicott, who was in charge of the Bengal party, proved that the rocks of the Raipur basin did not belong to the coal-bearing series as thought by the Rev. Hislop, but to the Vindhyans. He visited the Assam valley and established the existence of valuable coal seams to the south of the Brahmaputra river, the principal fields being those of Makum and Jaipur.

The North-West Himalaya

Mallet, Theobald and Stoliczka made expeditions to the Sutlej and Spiti valleys and the higher Himalaya to collect Mesozoic and Palaeozoic fossils as well as to work out the structure of these very interesting regions. The fossils collected were thought to range in age from Silurian to Cretaceous. Stoliczka's work introduced several stratigraphical names, such as 'Muth', 'Spiti', 'Kuling' and 'Lilang', etc. He also introduced the term "Central Gneiss" for what he regarded as the main geological axis of the North-West Himalaya. It is described as a porphyritic granitoid gneiss with veins of albite-granite.

In 1865, Stoliczka traversed the region from Simla to Srinagar and back, returning by a different route, in the course of six months, a feat requiring tremendous powers of endurance. The principal new discovery was that of the nummulitic beds of the Indus valley in Ladakh, which Stoliczka refers to as the Indus or Shingo beds.

Western India

Blanford pointed out the connection between the marine Bagh beds of the Narbada valley and the Lameta beds of Jubbulpore.

W. T. Blanford with Wynne and Wilkinson connected the western end of J. G. Medlicott's area in the Narbada valley with the sea at the Gulf of Cambay, the Bombay Island and Konkan, for which Oldham expressed justifiable pride and pleasure. Kutch and Sind were visited and Blanford

discovered in Kutch plant-beds of similar aspects as those of Rajmahal and Madras, the intercalated marine beds containing fossils of Jurassic age.

The Deccan trap

Working on the Deccan traps, Blanford pointed out that the rocks previously regarded as intrusive volcanic breccias were ash beds. He further noticed that the traps were horizontal and widely distributed and that they were of terrestrial origin with intertrappean beds containing fresh water fossils. He showed that they overlie the Bagh beds and are in places overlain with a marked unconformity by beds of nummulitic age and observes, "it appears highly probable that part, at least, of the traps are Upper Cretaceous in age." He suggests that the uppermost flows of Bombay and Mahabaleshwar might have been contemporaneous with the oldest Tertiaries. He also made the famous collection of zeolites which are now known all over the world. At the end of 1867, Blanford was deputed to accompany the British Military Expedition to Abyssinia as Geologist where he noted lava flows similar to those of the Deccan.

Madras

C. A. Oldham with King and Bruce Foote continued to work steadily northwards up the coastal tracts of Karnatic and the Coromandel section of the Eastern Ghats through the districts of Salem, South and North Arcot, Madras, Nellore, Cuddapah, Kurnool and Kistna. By the end of 1867 the party had completed the survey of an area of some 58,000 square miles. The metamorphic rocks were mapped and described at an age when the microscope was not in use, so that the gneisses of the Shevaroy hills and other mountain masses now known to be composed of hypersthene rocks are referred to as hornblende gneisses. They record the occurrences of bands of crystalline limestone in the Trichinopoly district, of magnesite veins in the Chalk hills

of Salem, and also of chromite and magnetitic iron-ores of Kanjamalai, near Salem.

Foote discovered fossiliferous beds (near Sriperimatur, south-west of Madras) in which Jurassic marine fossils were intercalated with others containing plant remains similar to those found in Kutch and in the Rajmahal hills. Similar plant beds were found by C. A. Oldham and King in the vicinity of Nellore.

Stone implements

King and Foote discovered stone implements over a wide extent of the country to the west and north of Madras city. Similar finds were later made by Ball and Theobald in other parts of India and Burma. Foote retained throughout the remainder of his service and life the interest thus aroused in stone implements, and the large and valuable collection made by him is now in the Madras Museum and is known as the Bruce Foote collection, containing 'precise similarity in form and design which exists between those found in India and those in Europe'. When discussing the stone implements of Burma, Theobald notes " . . . it would be difficult to say from shape or manufacture whether any particular implement of palæolithic type had been manufactured in Kent or Kuddapah, or if a particular neolithic belt of greenstone was from the neighbourhood of the Son or the banks of the Shannon".

Further expansion

With M. H. Ormsby recruited in 1866, Oldham's staff as it stood in 1868 was as follows :—

Deputy Superintendents :

H. B. Medlicott,	W. T. Blanford and
C. A. Oldham.	

Assistants :

W. Theobald,	W. King,
W. L. Willson,	R. B. Foote,

F. R. Mallet,
F. Fedden,
C. A. Hackett,

T. W. H. Hughes,
A. B. Wynne,
V. Ball and

M. H. Ormsby.

Curator :

A. Tween.

Palæontologist :

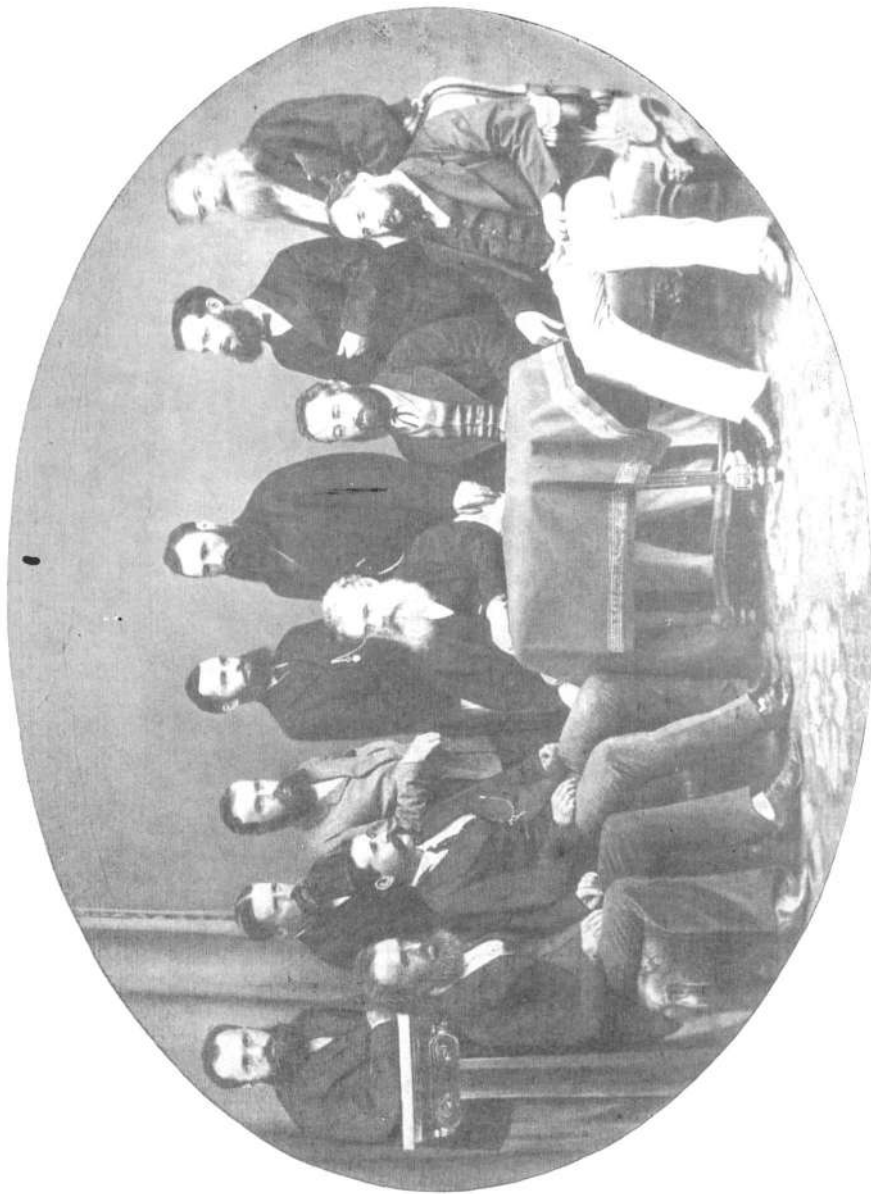
F. Stoliczka.

and the following officers were added to the staff until Oldham's retirement in 1876 to replace losses due to death and resignation : Mark Fryer (as Mining Specialist), Dr. W. Waagen, J. W. Alexander, James Willson, R. Lydekker, Dr. O. Feistmantel. The losses by death during this period were three in number, namely, Charles Oldham (1869), Ormsby (1870) and Stoliczka (1874), while J. W. Alexander and James Willson left the Department.

Among other appointments, though of a subordinate nature, mention should be made of that of Jules Schaumburg, who was appointed Chief Draughtsman to the department on the 12th April, 1869, and died on the 12th February, 1886. He will be remembered for the beautiful lithographed plates which adorn many of the Survey's publications. Mr. W. R. Bion was appointed as Librarian on the 12th December, 1870. He became Chief Clerk in 1875, and Registrar on 31st December, 1878, and died on 22nd July, 1891.

Due to Oldham's earnest endeavours an attempt was made to train Indian geologists through a system of apprenticeship, as geology was not taught in colleges in India at that time. Three students were recruited, Ram Singh in 1873 and Kishen Singh and Hira Lall in 1874. The two latter served with sufficient credit to be promoted as Sub-Assistants on the 1st April, 1879, and retired in 1903 and 1904 respectively.

Dr. Ferdinand Stoliczka on his return journey to India with a rich and valuable zoological collection from the



Standing.—F. STOLICZKA. R. B. FOOTE. W. THEOBALD. F. R. MALLET. V. BALL. W. WAAGEN. W. L. WILLSON.
Sitting.—A. TWEEN. W. KING. T. OLDHAM. H. B. MEDLICOTT. C. A. HACKET.

Yarkand Mission to Kashgar, during which he also visited the Pamir Steppe, met with death on the 19th June, 1874 at Leh. He had fallen "a sacrifice to his over-exertion in the cause of science" at an early age of 36. "He left behind him a noble monument of his research and powers in the *Palæontologia Indica* . . . in which, just before his departure for Yarkand, he had completed the description of the Cretaceous Fauna of Southern India in four large volumes".

Dr. Wilhelm Waagen, friend and associate of Stoliczka, was appointed Palæontologist on the 21st April, 1875, but owing to ill-health he was compelled to resign the service on the 24th August of the same year. Later, he became Professor of Palæontology at the University of Vienna. His principal contributions to Indian palæontology were a memoir on the Jurassic Cephalopoda of Kutch in the *Palæontologia Indica*; and after his retirement, a series of publications on the Salt range fauna.

Assam, Bengal and the Upper Provinces

Wynne and Waagen in the Punjab, Hacket and Willson in Rajputana, Hughes, Fedden and Ball (with Ormsby for a short period before his death) in Bengal and Bihar, continued their surveys, while Medlicott explored the Cretaceous coal-fields of the Garo hills, and the Shillong plateau, Khasia hills. He determined the nomenclature and sequence of the geological formations constituted by the Marine Tertiary and Cretaceous beds which bear a close affinity to the Cretaceous of Trichinopoly, and which rest unconformably on the Sylhet trap and the Shillong series held by him as equivalents respectively of the Rajmahal trap and the Dharwarians of Bihar.

Mallet examined the coalfields of the Naga hills where he established the main sub-divisions of the Tertiary sequence of Upper Assam in which coal and petroleum are found, and mapped the coal and petroleum occurrences. His main sub-divisions, the Dihings, the Tipam series, the Coal Measures

and the underlying Disang series have provided the basis of all subsequent geological work in the area.

Mallet mapped the Darjeeling district and the Bhutan Himalaya and found several coal outcrops belonging to the Damuda series and several occurrences of copper ore. The coal measures mark the northerly extension of the Gondwanaland. Besides the Tertiary beds and the Damudas, he separated the Baxa series, Daling and Darjeeling gneiss which dip into the hills and are superposed in the order named from the south to the north. He considered the Tertiaries to have been deposited at the foot of steep scarps of older rocks, the present line of junction representing the boundary of the original limit of deposition, possibly modified by subsequent faulting. This line is what was later to be regarded as the Great Boundary fault of the Himalaya. Among the older rocks, he, like Medlicott in the North-Western Himalaya, was not prepared to recognise inversion, so that he regarded the Baxas, Dalings and the Darjeeling gneiss younger than the Damudas.

Mallet continued his Son valley work into the southern parts of Mirzapur and adjoining parts of Rewa and mapped the coal occurrences of Kota in the Singrauli coalfield.

Ball continued his survey of Manbhum and Singhbhum where he made a special study of the 80-mile long copper belt, and of the Bistrampur coalfield, the Raigarh-Hingir coalfield in Gangpur, of Chotanagpur and Sirguja, the Mahanadi valley between Sambalpur and the Talchir coalfields. His Singhbhum map has been a source of information to all subsequent workers, both geologists and mining men. The crystallines were divided into two groups, Sub-Metamorphic or Transition, and Metamorphic, the former group being now regarded as corresponding largely with the Dharwarians of South India.

The Satpura Coal-basin and the Gondwana system

H. B. Medlicott devoted most of the time from 1868-69 onwards till Oldham's retirement to problems connected with

the coalfields, particularly those of the Satpura, Mohpani and Shahpur (Betul). His conclusions on the Satpura basin coincided with those of Hughes with regard to the Bengal coalfield, that the present limits of the coal measure rocks coincide approximately with the original limits of deposition and are not the results of faulting or of denudation. With regard to the coal-bearing rock systems, the most important nomenclature proposed by him was the Gondwana system, after the ancient Gond Kingdom, which extended from Chanda into the Satpuras.

On more detailed maps being published, Medicott started the revision of the geological maps of Central India and the Central Provinces, the Deccan trap, the Bundelkhand gneiss and the Bijawars in 1870.

Hackett's work lay mainly in the Jubbulpore district and in the adjoining area of Gwalior, where he introduced the term Gwalior series, and westwards into the Aravalli region in Rajputana, where he introduced the term Aravali series for the rocks largely composing the Aravalli range. He later introduced the term Delhi series for what he thought to be the younger members of his original Arvalis. He still retained the term Arvali series for the rocks constituting the high hills of the Aravalli range. The later work of Middlemiss and Heron has however proved these to be highly metamorphosed members of the Delhis.

The Salt Range, Attock and the Trans-Indus Salt region of Kohat

Wynne, who was assisted by Waagen in the palæontological work, separated 15 groups of strata in the Salt range ranging from post-Tertiary down to his 'Obolus beds' (regarded as Silurian at the time) and to the underlying Purple sandstone and the basal Saline series. Although subsequent palæontological studies by Waagen and Warth have modified the ages ascribed by Wynne to some of his groups, his work securely laid the foundations of our knowledge of the

stratigraphy of this part of India; and his conclusion that the Purple sandstone and the Saline series below it, rest with a normal superpositional contact beneath his *Obolus* beds, according to the latest stratigraphical work of Gee, still stands valid.

Kutch

Wynne and Fedden investigated respectively the marine Jurassics associated with plant beds which were divided into two groups, and the Tertiaries, of Kutch. Stoliczka visited Kutch later and established the now familiar sub-divisions of the Jurassic, Patcham, Chari, Katrol, and Umia, the last ranging into the Lower Cretaceous. The Cephalopods of Kutch were described by Waagen, but the remainder of the rich collection made by Wynne, Fedden and Stoliczka were not described until recently.

Dr. Feistmantel, who joined in 1875, took up the description of the fossil floras of the Gondwana system in the *Palæontologia Indica*, his first contribution being on the Jurassic (oolitic) Flora of Kach. He pointed out that there was a palæontological contradiction between the evidence of the animal and the plant remains: the plants indicating a somewhat greater age than the animals.

The Wardha Valley Coalfield

Mark Fryer, specially appointed Mining Specialist, conducted boring operations in the Chanda district during 1868-69, with Oldham himself coming to the C. P. to control the operation. Hughes who commenced surveying in this region from 1869-70 continued until 1873, controlling the operations afterwards. He grouped several areas of coal-bearing rocks, which he separated from the Upper Gondwanas of the Wardha valley, under the new term Kota-Maleri.

The Kota beds contained fossil fish discovered by A. M. Walker in 1850 and T. L. Bell in 1851, and plants discovered by Hughes and King; whilst the Maleri beds contained fish

teeth and reptilian bones discovered by the Rev. Stephen Hislop in 1859, and were older than the Kota stage. Besides the Gondwana tract, he mapped a large portion of this part of India with Fedden, and showed it to be composed of Vindhya's (King later separated the lower portion as Cuddapahs), Gondwanas, Deccan trap, Lamets and Metamorphics. He estimated 2,000 million tons of coal, of which only a portion could be regarded as available, while Tween's analyses showed that whilst much of it was of fair quality it was non-coking.

The Sind Tertiaries

Blanford's and Fedden's researches in Sind during 1874-76 showed that the Tertiaries there ranged in age from Lower Eocene to Pliocene, and to the various divisions recognised ranging from Infra-Nummulitic to Supra-Nummulitic and Siwalik Blanford allotted the now well-known names Ranikot, Laki, Khirthar, Nari, Gaj and Manchar, the later being regarded as equivalent to the Siwaliks. The completed survey of the region which took a year longer, showed the existence beneath the Ranikot stage of rocks regarded as Cretaceous, consisting of *hippurite* limestone overlain by *Cradita beaumonti* beds (Upper Cretaceous-Eocene). Their discovery of two lava flows (correlated with the Deccan trap flows) between the *Cradita beaumonti* horizon and the Ranikot beds, and a third one interstratified in the sandstone underlying the *Cradita beaumonti* beds threw light on the time period of the lava flows in this region which has a bearing on the question of the age of the flows—a subject of much controversy lately

The Madras Party

The work of C. A. Oldham, King and Foote during the period led to the mapping of the Cuddapah and Karnool basins, and their subdivision into stages, and the discovery of the Upper Gondwanas of Guntur and Ongole. On C. A. Oldham's death in 1868, King was appointed Deputy Superintendent for

Madras and he continued with Foote the mapping of the Southern Mahratta country and adjacent districts. Foote recognised two principal elements in the gneissic rocks, *viz.*, of granitoid and schistose nature, arranged in great bands traceable for miles with a general N. N. W.-S. S. E. strike. The schist bands he was later (1886) to separate from the gneissic complex as Dharwars.

Burma

Theobald's work in Burma from 1867 to 1872-73 laid the foundations of our knowledge of the geology of Burma from Cape Negrais up to latitude $19^{\circ}30'$ North. Of the terms proposed by him to designate his Burmese formations, the well-known ones are Fossil-wood group, Pegu group, Negrais group and Axial group. He also gave an account of the petroleum occurrences and of brine springs.

Oldham introduced the practice of sending officers of the department with trans-frontier and overseas expeditions, e.g., W. T. Blanford in Abyssinia (1867-68) and Persia (1871-72), Stoliczka with the Yarkand Mission (1873-74) and himself with Phayre's Mission to the court of Ava in 1855. In the course of such work on the Baluchistan-Persian frontier, W. T. Blanford proposed the name of Makran for the younger marine Tertiary beds along the Makran coast of Baluchistan, and also the Hormuz salt formation of the underlying beds of the Hormuz Island.

Economic Geology

A large proportion of the work was directed to the coalfields and special Memoirs were written on the subject. In addition, iron-ores, limestones and building stones, the salt deposits of the Punjab, the oil springs of Assam, the Punjab and Burma, and numerous minor occurrences of a great variety of other minerals were described in the Memoirs of the surveyed areas. The copper deposits of Dhalbhum and Singhbhum and of the auriferous rocks of the Dambal hills.

Dharwar district, and gold in the Wynaad may also be mentioned in this connection.

Next to coal, the most important problem was the possibility of producing the iron needed for the construction of railways. Iron works were established in Kumaon from 1857-60, using local iron-ores and wood as fuel. Although in the Department's opinion the Raniganj coalfield area was the most promising place for a trial, a specialist was sent out from England by the Secretary of State for India to give a definite opinion on the feasibility of establishing iron works in India. The specialist, Mr. Hilary Banerman, who was accompanied by Mr. Ball, reported unfavourably on the Kumaon venture. The local authorities were not satisfied; so Mr. T. W. H. Hughes was deputed to make a further report which was also adverse. Nevertheless, the Government did again embark on the manufacture of iron in Kumaon from 1877-79, despite the emphatic language, evoked by hurt feelings, with which Mr. Medlicott commented on Banerman's visit, in the Annual Report for 1874. To quote Medlicott:—

"Even if Mr. Banerman's deputation to India had not so directly touched upon the work of the Geological Survey, it would call for notice here. He is the latest of a series of experts . . . Mr. Banerman has simply re-stated the case in a more intelligible form than some of his predecessors, but no more than it has all along been expressed by the Geological Survey . . . that under the existing circumstances, the Raniganj coalfield is the most promising place for a trial . . ."

Oldham also initiated the study of earthquakes in India, himself taking the field in 1869 after the Cachar earthquake. He prepared the first catalogue of Indian earthquakes. He also prepared the first list of thermal springs in India and listed 301 springs.

With the aid of his staff, a large proportion of India was surveyed geologically and the compilation of the first authentic geological map of India was commenced in his time to be ultimately published in the year following his retirement.

The Indian Museum

In 1835, the Government of India, encouraged by the opening up of the Raniganj coalfield, decided to found a Museum of Economic Geology. This was effected in 1840, and the collections were housed with the Asiatic Society, until 1856, by which time the house newly acquired at 1, Hastings Street for the Geological Survey had been adapted for Museum purposes. The collection was then moved to Hastings Street and the Geological Museum was opened to the public on 1st January, 1857.* These changes were a part of the re-organisation of the Geological Survey of 1856 for which Oldham was responsible, and from 1856 Oldham used the dual title of Superintendent of the Geological Survey of India and of the Museum of Geology, Calcutta, a designation which was altered in his Annual Report for the year 1863-64 to Superintendent, Geological Survey of India and Director of the Museum of Geology, Calcutta.

In 1856 the Asiatic Society had moved the Government for the foundation of a public Museum in Calcutta to house its collections. In May, 1862, Government announced its intention to consider the matter, and after protracted negotiations lasting until the middle of 1865, it was provided that the Society should be given suitable and exclusive accommodation in the Museum besides retaining its house at 1, Park Street, and legislative sanction was given to the conditions in the Indian Museum Act (No. XVII) of 1866.

By the time the Museum was constructed, the collections had grown, and the Board of Trustees were of opinion that the whole accommodation would be ultimately required for Museum purposes by the Geological Survey and the Natural History Museum, but the Asiatic Society felt that their position as an independent body would be injured if housed with these two large establishments. The Government thereupon referred the matter to a Committee consisting of 'one of the most sagacious administrators and one of the acutest scientists of

* Only some 5½ years after the opening of the Museum of Practical Geology at Jermyn Street in London (12th May, 1851).

the country, Sir Ashley Eden and Dr. Thomas Oldham'. Upon their joint recommendation, the Government of India paid to the Asiatic Society Rs. 1,50,000 as compensation for its claim to accommodation in the Museum buildings. This arrangement has proved highly beneficial both to the Society and to the Museum.

It was not till 1875 that the Museum building became ready for occupation, when the Geological Survey moved into new quarters, although the transfer of specimens of the Geological Survey from 1, Hastings Street probably started in 1874. The old quarters in 1, Hastings Street were vacated on 30th September, 1875, and the new geological galleries were thrown open to the public on the 1st January, 1877, with the specimens of the Asiatic Society amalgamated with those of the Geological Survey. The Asiatic Society specimens included a valuable, though small, collection of Siwalik vertebrates.

Union of two lineages

From the facts related above it is interesting to reflect that with the re-organisation of the Geological Survey of India in 1856 two lineages were combined: that which dated from the arrival of Williams in 1846 as Geological Surveyor to the East India Company and, after a break, was continued with Oldham's arrival in 1851 to burgeon into the Geological Survey of India; and the second lineage, starting with the foundation of the Museum of Geology by the Government of India in Calcutta in 1840, housed in the rooms of the Asiatic Society of Bengal, so that the Museum section of the department has a more ancient origin than the Survey section.

WILLIAM KING

1887—1894

Dr. William King succeeded H. B. Medlicott in April, 1887, as Director, Geological Survey of India. He was then already 54 years old, but the Government of India, relaxing the retiring age rule, granted him six extensions year by year and thus retained his services until 20th July, 1894. At the time of his retirement he was 60 years old and had put in a record service of 37 years.

During his Directorship no important change took place in the cadre of the Department and the number of geological officers varied from 12 to 14 in the graded category (including the Director and the Palæontologist). During this period the Department lost six officers, three by retirement, one by resignation and two by death, and their places were filled by six new appointments. The out-going officers included C. A. Hackett, retired in July, 1888, after 27 years' service; F. R. Mallet, retired in June, 1889 on invalid pension after 30 years' service; and R. B. Foote, retired in July, 1891 after 33 years' service. Subsequent to his retirement Foote accepted the post of State Geologist in Baroda where he remained for three years, and then moved on to Mysore as its State Geologist. P. Lake, who had joined the Department in October, 1887 only, was forced to retire after a little more than three years' service in January, 1891 for reasons of ill-health. The losses sustained owing to death were those of F. Fedden and E. J. Jones. The former died of heart failure on 27th December, 1887 while on field duty in the Vizagapatam (now called Vishakhapatam) district, and the latter died of dysentery in Darjeeling in October, 1889.

The officers recruited during this period included Parvati Nath Dutta, Thomas Henry Holland, William Bruce Dallas Edwards and Frederic Herbert Smith. Besides the above officers, Dr. H. Warth, also known as Hugo Signund



W. KING

Freiderich, was transferred in September, 1890 to the Department from the Forest School, Dehra Dun. Ten months later, in July, 1891, he went to Madras as the Superintendent of the Museum, subsequently returning to the Survey in December, 1893.

Coal Surveys

Attention continued to be focussed on the coal-bearing rocks of the Peninsula during this period and various investigations were taken up to prove their economic possibilities. In 1887 King, Bose, Kishen Singh and Hira Lal investigated the Chhattisgarh coalfields by borings, and came to the conclusion that Korba, which had been found by Hira Lal in 1884, was the only workable area. Hughes, in 1888, after a thorough survey of the coalfields in Hyderabad, found that the potentiality of good coal there was far greater than at Umaria or Karharbari. About the same time Jones investigated the Rajmahal coalfields, which on subsequent exploration gave disappointing results. It was now that King for the first time suggested that drilling equipment and personnel should be attached to the various parties of the Geological Survey of India, so that exploration might be expedited.

King continued his investigations on the coal measures of Chota Nagpur and Chhattisgarh until 1890. La Touche working in Daltonganj in 1890, proved that the coal measures in this area were poor. His work in 1892, in the Mohpani area, resulted in locating good quality coal seams towards the western portion of the field.

Archæan Surveys

Extensive mapping of the Dharwar rocks was carried out in Mysore State and in the Anantapur, Bellary, Kurnool and Cuddapah districts of the Madras Presidency by Foote, Fedden, Lake and Hughes. A detailed investigation of the gold deposits of these areas was a valuable contribution, but

an attempt to locate the source of diamonds in Bellary was unsuccessful.

In 1891 Holland examined the Nellore mica mines and steatite quarries in Kurnool, and in the following year discovered large deposits of high grade iron-ore, chromite and magnesite in the Salem district, and investigated the deposits of corundum in Mysore. This latter investigation was taken up with a view to exploring the possibilities of establishing an aluminium industry, which was attracting considerable attention at that time.

In 1893 Holland discovered in Madras an acid, pyroxene-bearing rock, which seemed to be a type of igneous rock hitherto undescribed, the pyroxene being generally of the rhombic variety, hypersthene. For this rock he proposed the new name Charnockite, after Job Charnock, the founder of Calcutta, from whose tombstone in St. John's churchyard was received the first specimen examined under the microscope. This led to further detailed field and laboratory work, with the establishment of a new petrographic province comprising a suite of rocks varying from acidic to ultrabasic in composition, yet exhibiting a distinct 'consanguinity' to each other, the most important common factor being the presence of the rhombic pyroxene, hypersthene, in all cases.

Bose, in 1888 and 1889, mapped the Vindhya and the metamorphic rocks in the Balaghat district in the Central Provinces (now called Madhya Pradesh). The latter were grouped under the name of Chilpi Ghat series and were at that time regarded as a part of the Transition series or the Bijawars. It may be mentioned here that he was the first person to introduce into the Geological Survey of India the study of micro-sections as an aid to petrological work, and to give accounts of micro-sections in Progress Reports.

Jones, in 1889, made a detailed examination of the dolomite of Dhelwa in Hazaribagh and of limestone at Raniganj, Simultala and Panchet hill. This investigation was taken up in connection with the increased demand of these materials for the iron industry at Barakar, and Jones was able

to prove that limestone of desired quality was available in sufficient quantity.

Extra-Peninsula Surveys

The Himalaya, as ever, continued to be a centre of attraction throughout this period, and a band of enthusiastic workers were engaged in stratigraphical, palæontological and economic investigations in the various parts of the mountain ranges. From 1887 to 1889 C. S. Middlemiss worked in the Sub-Himalaya of Garhwal and Kumaon, and Oldham in the region west of Hardwar up to the Sutlej, where the Siwaliks were mapped and their relationship with the older Himalayan formations was determined.

Warth, working in the Salt range in 1888-89, made the very interesting discovery of trilobites in the *Neobolus* beds, which definitely fixed their age to be Cambrian. Subsequently extensive field work was done by King and Middlemiss in 1889, and by Middlemiss and P. N. Datta in 1890, which helped to fix the position of the unconformity between the Upper and the Lower Palæozoic, Middlemiss ascribing a Tertiary age to the Saline series, and considering it to be probably of the nature of a hypogene intrusive during the mountain building epoch.

Griesbach, who was well-known for his ability in sketching, carried out extensive work in the Central Himalaya between the Spiti valley and the frontiers of Nepal, where he met formations ranging from pre-Cambrian to Tertiary. In 1879, he introduced the term *Vaikrita* (Sanskrit for metamorphosed) series for the schistose Dharwarian rocks north of the Central Himalaya, and the *Haimanta* system for the Cambrian rocks of Spiti, the latter name referring to the occurrence of the rocks in the high, snow-capped peaks.

Griesbach's collection from the Triassic was very fine, and his work in the Central Himalaya attracted great attention abroad, particularly of Prof. E. Suess of the Imperial University, Vienna, who remarked that ' . . . the discoveries

are so important that it seems well nigh our duty to follow them up as far as we possibly can'. Subsequently Suess arranged for Dr. Diener to come out to India to make further collections from that area, and an expedition was arranged in 1893. Griesbach and Middlemiss joined this expedition, which proved to be a great success.

Assisted by Kishen Singh and Hira Lal, Oldham was able to locate in 1890 promising 'oil shows' at Spintangi, Pir and Kipar Mand in Baluchistan. He also recorded the occurrence of an 'oil show' near Kirta in the Bolan valley and at Moghul Kot in the Sherani country, on the north-west side of the Sulaiman range. The latter occurrence was further investigated by La Touche in 1892, when he found that the rate of flow of the oil was too slow. La Touche further utilised the opportunity to record a detailed account of the geology of the area. In the same year King supervised the boring operations for oil at the Chapper Rift on the Sind Pishin railway, which, however, proved to be fruitless.

The coalfields of Assam were also actively explored during this period. La Touche found the deposits in the Khasi and Jaintia hills to be very promising. In the Garo hills, Datta, in 1891, found that the only field offering immediate prospect of successful development was that of Daranggiri. Bose carried out investigations in Darjeeling from where he reported a certain amount of good quality coal which, however, occurred in steeply dipping beds, and was very much crushed. In Sikkim he examined the copper deposits, which were found to be fairly promising. He also wrote an interesting note on the elevation and disturbances in the Sikkim Himalaya.

A number of economic investigations in Burma were also included in the programme of the Survey during this period. Between 1888 and 1891 Noetling investigated the oilfields of Yenangyaung and demarcated the oil-bearing zones. He also investigated the iron-ores, ruby and tourmaline occurrences in the Shan States, coal in Chindwin and amber and jade deposits in Upper Burma.

Between 1888 and 1892 Hughes examined the tin deposits in Tennasserim, which were finally proved to be quite promising. Bose and Datta also worked in the Tennasserim valley in 1892 and 1893, where they found large supplies of coal.

Education

In 1892, the Geological Survey of India assumed the additional responsibility of imparting education in Geology. In collaboration with the Government of Bengal it agreed to allow one of its officers to work as part-time professor of geology at the Presidency College, Calcutta, and Holland was the first officer to be deputed for the work.

C. L. GRIESBACH

1894—1903.

Griesbach assumed charge of the Department on 20th July, 1894. He was then 47 years old, and had very valuable work in Afghanistan, Persia and Turkestan with the Boundary Commission and in the Central Himalaya to his credit. In 1902, when he attained the age of 55, the Government granted him an extension for one year, at the end of which he retired, having served for 25 years in all.

During the period of his Directorship an important addition to the cadre of the Department was made in the appointment of several mining officers, the want of which had been keenly felt by his predecessor King in explorations for coal and oil, etc. The posts of Specialist in Mining and Metallurgy and the Inspector of Mines were created to which, in 1894, William Anderson and James Grundy were appointed respectively. Anderson, however, resigned in 1896, and his post remained vacant until the appointment of George Alfred Stonier in October, 1899. The posts of a specialist in coal mining and of another in gold mining were also introduced. George Frederick Reader joined the first post in November, 1899, and Frederick Henry Hatch the second in March, 1900. Reader unfortunately died of cholera in Madras in March, 1901 and his vacancy was filled by Robert Rowell Simpson in October, 1901. Hatch resigned in 1901, and James Malcolm Maclaren was appointed in his place in 1902.

Early in 1902 the mining side was separated from the Geological Survey of India, the mining specialists being transferred to the newly created department of the 'Bureau of Mines Inspection' under the Specialist in Mining and Metallurgy, henceforward called the 'Chief Inspector of Mines'. In 1904 the name of this new department was changed to the 'Department of Mines', and its office was



C. L. GRIESBACH

shifted to No. 9, Pretoria Street, Calcutta and subsequently to Dhanbad.

On the geological side the Department lost three of its older officers during this period. The first was T. W. H. Hughes, who was obliged to retire in October, 1894, having lost his eye-sight in an unfortunate accident met while out on a shooting trip early in January, 1893. It is said that he was very fond of *shikar*, and that he wrote his reports sitting in a *machan* while waiting for tigers, of which he had a hundred to his credit. The second loss was that of W. B. D. Edwards who resigned in June, 1894, to take up a post of Inspector of Schools in England. Finally Dr. H. Warth retired on 15th March, 1896.

The new appointments during this period numbered seven, viz. Henry Hubert Hayden (1895); Ernest Watson Vredenburg (1895); George Ernest Grimes (1895); Albrecht von Kraft (1899); Thomas Leonard Walker (1897); Lewis Leigh Fermor and Henry Guy Ellcock Pilgrim (1902). Of these, three did not stay with the Survey for long; Grimes died of cholera in Burma in April, 1898, Kraft died in Calcutta in September, 1901, and Walker resigned in December, 1901.

It was during this period that the Survey moved into its present building, which was erected by the Government of Bengal under an agreement with the Trustees of the Indian Museum. The removal took place in the summer months of 1897, the year of Queen Victoria's Diamond Jubilee. Earlier, Griesbach had suggested the advisability of removing the headquarters of the Survey to a hill station where, he thought, the maps and reports could be completed better than in the hot plains. The Government, however, did not accept this proposal.

South Indian Surveys

Middlemiss, Smith and Holland carried out extensive surveys in the various parts of the Madras Presidency during this period. The investigations pursued by Middlemiss and Smith in 1894-95, which were chiefly of a petrological

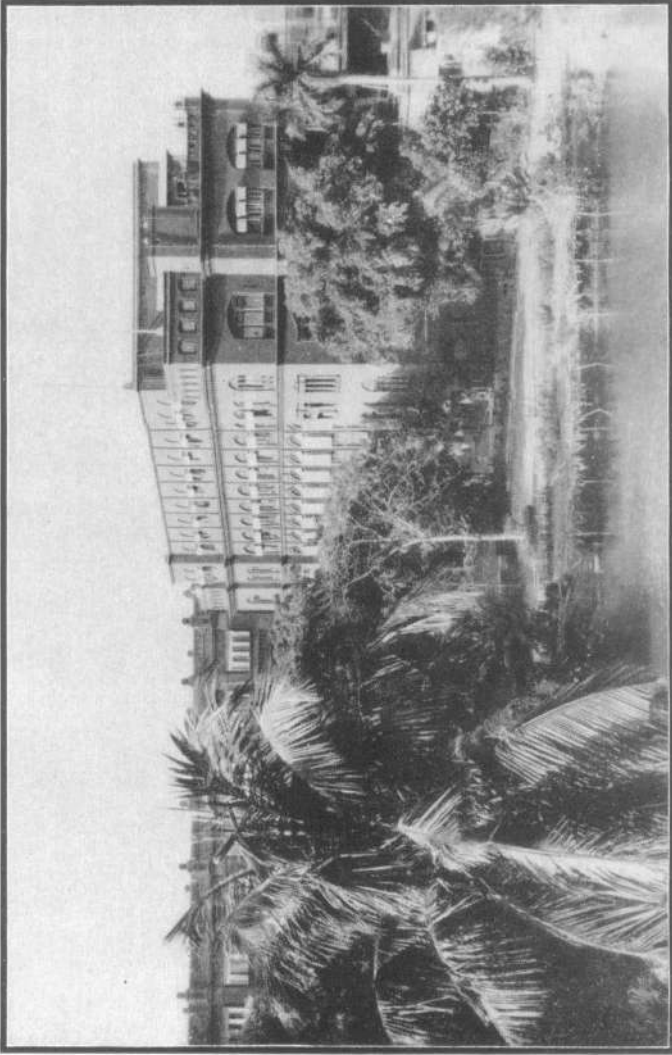
character, added much to our knowledge of the nature of occurrence of magnesite and corundum in Madras. Later, Middlemiss and Holland were engaged in the survey of the Salem and Coimbatore districts. Subsequently, Holland studied the corundum-bearing rocks of India, which led to some very interesting facts in connection with the paragenesis of this mineral, particularly with regard to its relation with the pyroxene-granulite series, so largely developed in Madras, and he came to the conclusion that corundum is an original, and in fact the first formed, constituent in these rocks. He further pursued the study of the hypersthene-bearing rocks, the charnockites, which he had discovered in 1892-93, and on which he finally wrote his classic memoir, published in 1900.

Walker, who remained in the Department for barely four years, worked mainly in the Eastern Ghats of Madras and Orissa. Studying the rocks in this region he introduced a new term in Indian petrology, 'khondalite', for a group of para-schists including garnetiferous quartz-sillimanite rocks, calciphyres and graphitic schists. In collaboration with Dr. Collins of the Canadian Geological Survey, Walker also described the very interesting sapphirine-bearing schists from the Eastern Ghats.

The work of the Mining Specialists

The Mining specialists who had been appointed early in this period commenced their investigations with the study of the auriferous rocks. By now gold mining had developed considerably in this country and the introduction of improved metallurgical processes had made it possible to work low-grade ores profitably. It was therefore decided to make a detailed examination of the known auriferous tracts. In 1894-95 W. Anderson explored a considerable area in Chofa Nagpur. In the following season he was assisted by H. Warth and Hira Lal, but the results were not encouraging.

Regions in Burma and South India were put in the charge of Stonier and Hatch respectively. The former confined his attention to the Wuntho district in Burma and the latter, along



V. P. Sondhi, Photo.

GEOLOGICAL SURVEY BUILDING, CALCUTTA

with Hayden, examined the important reefs of Kolar and Wynaad. The general result of this examination tended to show that the majority of the reefs in Wynaad were too poor to offer any prospect of remunerative working.

In 1899-1900 G. F. Reader, the specialist in coal mining, examined at length the coalfield of Rampur, where F. H. Smith had earlier established the sequence and structure of the coal-bearing strata. Reader selected a site for a bore-hole to be driven down to the level of the Talchirs. He also examined the Sohagpur coalfield in South Rewa, and reported that out of seven seams, two were of workable thickness and of very fair quality.

Vindhyan and Gondwanas

P. N. Bose covered an area of about 2,000 square miles in Rewa in the field season 1893-94, where he recognised the Gondwana, Vindhyan, Transition and metamorphic formations. In the following season Oldham mapped another 700 square miles in this region, when he separated the Lower Vindhyan from the Upper. He also correlated the rocks of the Transition stage with the Haimanta group of the Himalaya. Subsequently P. N. Dutta, E. Vredenburg and G. E. Grimes also joined the party working in Rewa and helped to complete the work in 1897, as a result of which large areas were added to the known outcrops of Damudas and several new coal seams were located.

Rajputana Survey

La Touche resumed the survey of Rajputana in 1896, and pursued it up to 1898, during which period he studied the Malani volcanic series and the Aravalli rocks. He also investigated the coal occurrences at Palana, in Bikaner, where he found that the thickness of the seam varied from 20 inches to as much as 20 feet, and suggested exploration by boring. In 1899-1900, however, when Griesbach re-visited the area, he was told that according to the State Engineer enough

coal was actually in sight to meet the probable requirements of the Jodhpur-Bikaner Railway for about 15 years, hence it was unnecessary to undertake any 'proving' operations.

Extra-Peninsula Surveys

In continuation of the work done by R. D. Oldham in Baluchistan, Smith mapped, in 1893-94, some 2,000 square miles of very interesting country around Mari. About the same time Griesbach completed an accurate survey of about 3,400 square miles west and north-west of Quetta. Kishen Singh mapped about 600 square miles of the country and made a most valuable and systematic collection of fossils, which were later examined and described by Noetling. In 1898-99 Noetling mapped portions of the western Mari hills and the Zhob valley, covering the areas left blank by R. D. Oldham and Smith in that area. He collected a large number of fossils and described the formations in great detail.

Vredenburg accompanied the Political Assistant on his tour in the district of Chagai and adjoining territories, and availing of the opportunity, geologically examined part of the desert of north-western Baluchistan and eastern Persia. In his report he gave details of two extinct volcanoes in that region. Working in Baluchistan, Sind and Makran, Vredenburg mapped about 60,000 square miles of the country, which still forms a very distinctive part of the geological map of India and Pakistan. While modifications may be required in detail, when large scale topographical maps are available, the delineation of the basic structure is correct and is a monument to Vredenburg's work in a most difficult and waterless terrain.

Working in the Salt range in 1893-94, Noetling made a detailed study of the Lower Palæozoic rocks in the Khusuk section, from which he obtained a large collection of fossils that was forwarded to Waagen for determination. Six years later, revising the work of Wynne and Waagen in parts of the Salt range, he established that there was no stratigraphic

break between the Upper Palæozoic and Triassic beds in this area, the lower beds, full of Palæozoic brachiopods, gradually passing into the upper beds bearing abundant ammonites.

In 1897 Hayden accompanied the Tirah Expeditionary force. His work in this region helped to establish the truth of the supposition that the Palæozoic and Triassic rocks make their appearance along a great dislocation, running from east to west, which represents the main mass of the Safed Koh range. Subsequently he proceeded to the Kangra Himalaya, where between 1898 and 1900, assisted by von Kraft to a certain extent, he mapped almost the whole of the Spiti valley area, leaving only some snow covered, very inaccessible ranges facing Hundes, and was able to make a very systematic collection of fossils from almost all the beds ranging from Cambrian to Cretaceous. His discovery of fossils from the Lower Palæozoic horizons was of particular importance. He also paid considerable attention to the Upper Trias, which was found to be more complete than had been regarded hitherto.

In the Kumaon Himalaya also La Touche, Smith and Walker examined the Upper Triassic beds and made a very good collection of fossils.

Between 1901 and 1903 P. N. Bose carried out extensive mapping in the Jaintia hills, Assam, from where he reported good quality coal seams at Wapung, Lenkensmit and Barapani, and rich deposits of fire-clay near Jowai.

Noetling's enquiry into the occurrence of oil in the neighbourhood of Yenangyaung in Burma was brought to a successful close towards the end of the field season 1894-95. In his report, which was comprehensive and published in the form of a *Memoir*, he arrived at the conclusion that the field would not last for long.

La Touche and P. N. Datta worked in the Shan States during 1899-1900, when they mapped the very interesting black graptolite shales with the underlying trilobite beds of the Zebingyi series. About the same time Middlemiss made rapid traverses across the southern Shan States and Karenni

hill, and examined the lead, silver and copper mines near Bawzaung and Myinkyardo, coal near Inwun and lignite in the Thamkan plateau. He also investigated the occurrence of 'greenstones' near Namon on the Salween river, which were being collected as gems, and found that the 'stones' were green tourmaline occurring in a matrix of crystalline limestone.

Engineering Geology

As a sequel to a big landslide, which dammed the valley of Birahi Ganga, Holland examined the geographical and geological features of the valley, and tried to analyse the causes which led to the landslide. The problem of the safety of the Government House hill, Naini Tal was examined first by R. D. Oldham in 1895, and again by Holland in 1896. The latter in his report discussed the dangers apprehended and the remedial measures to be undertaken.

In 1898-99 the Survey was called upon for the first time to investigate the suitability of dam-sites. The enquiries came from the Mysore and Madras Governments, who were interested in damming river valleys for irrigation purposes. The former proposed to build a dam at Marikanava in the Chitaldrug district, and the latter planned to dam the Bhavani valley in the Coimbatore district. Holland undertook the investigations and submitted reports to the respective Governments.

In 1900 Griesbach visited parts of the Central Provinces (now Madhya Pradesh), Gujarat and Rajputana with a view to ascertain, if possible, the chances of increasing the water supply by means of artesian borings. His advice proved to be very valuable.

The Great Assam Earthquake

An important investigation taken up during this period was that of the earthquake of the 12th June, 1897, which rocked the earth most violently and affected places far and wide over an area of about 1,275,000 square miles. The epicentre lay in Assam, which suffered the maximum damage. The Government

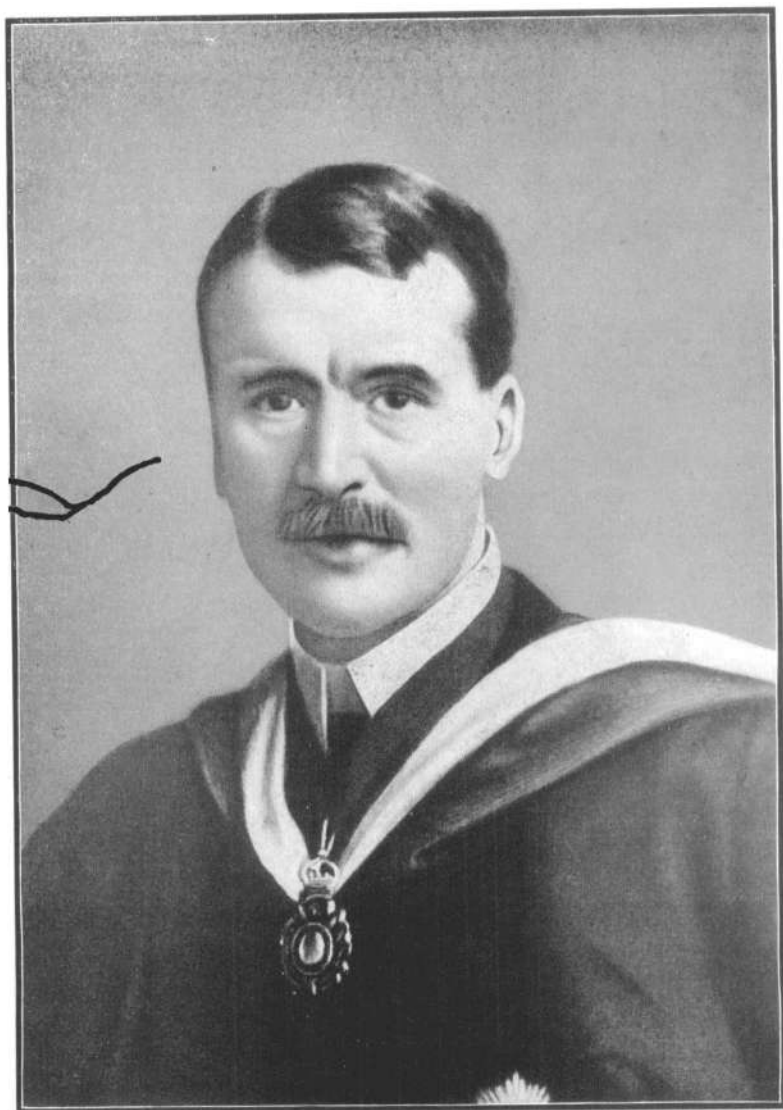
of India decided that a most searching enquiry should be made, and accordingly a party consisting of Oldham, La Touche, Bose, Smith, Hayden, Vredenburg and Grimes was constituted to carry out the investigation, the results of which were embodied in one of the *Memoirs* of the Department, a memoir that has been described as being 'worthy of a great subject.'

T. H. HOLLAND

1903-1910

Holland was only 34 years of age when he became Director on the 25th February, 1903. His appointment involved the supersession of several senior officers, amongst whom were R. D. Oldham, C. S. Middlemiss and T. H. D. La Touche, all men of high quality. Oldham retired on the 1st May, 1904.

Holland had joined the Department in 1890, and from the very first showed a flair for the study of mineral deposits. His outstanding work, however, was that on the Charnockites of South India. He was for a time Curator of the Geological Section of the Indian Museum which then, as it is now, was under the care of the Geological Survey of India. He ~~did~~ much to organise and arrange the Geological Museum and was also responsible for organising the Geology Department of the Presidency College, Calcutta, as a part-time professor. This arrangement with the Government of Bengal in regard to the appointment of a part-time professor of an officer of the Geological Survey of India still continues. During the period of his Directorship Holland's personality was felt in many directions. He was instrumental in laying the foundation of the Mining and Geological Institute of India (now the Mining, Geological and Metallurgical Institute of India) and was its first President in 1906. In his second Presidential address in the following year, Holland defined the aim of the Government geologist in this country to be that of helping in the development of the mineral resources of India. He also emphasised the importance of the study of the mineral deposits without neglecting the academic side of geological mapping and for which he had to bear some criticism from the Geological Society of London and the Royal Society of England through the India Office, which used to send his Annual Reports to those bodies for their opinion. Holland re-organised the work of the Department and raised its status in the eyes of both the



T. H. HOLLAND

Government and the public. He was responsible for taking over the duty of collecting and co-ordinating the statistics of mineral production in India under the auspices of the Geological Survey. These statistics were till then annually collected by the Revenue and Agriculture Department of the Government of India by people who had no knowledge of geology or minerals. In addition to issuing a review of the mineral production and mineral industries of India annually, Holland organised a quinquennial review of mineral production, the first of which series covered a period from 1898 to 1903. The pattern evolved by him for annual reports, review of mineral production, publications, etc., is still followed by the Survey.

Holland was instrumental in getting the Geological Survey of India made responsible to Government for advice on policies relating to mineral concessions, including oil, in India and Burma. He secured from the Government of India an increase of staff and better terms of pay, and initiated comprehensive surveys of the coalfields of India, the oilfields of India and Burma and the manganese-ore deposits of Central Provinces. Attention was also given to the deposits of bauxite in various parts of India and also to a detailed investigation, by diamond drilling, of the Singhbhum copper-ore deposits that are being worked at present. The latter work was entrusted to K. A. K. Hallows, and the story of the Singhbhum copper-belt as a modern industrial proposition really dates from this work of the Geological Survey of India. Most of the mineral investigations started during Holland's regime were completed during the Directorship of his successor, H. H. Hayden, and monumental work of L. L. Fermor on the manganese-ore deposits of India was published in 1909, shortly after Holland's taking leave preparatory to retirement.

It was during Holland's period as Director that P. N. Bose, who is accredited with the discovery of most of the well-known iron-ore deposits of Central Provinces and Bastar, conducted, after his retirement from the Department, a survey of Mayurbhanj and succeeded in discovering large deposits of iron-ore which led to the foundation of the great

enterprise of the Tata Iron and Steel Company. The idea of exploiting these deposits for establishing an iron and steel works by this company received strong support from Holland, who visited the area himself.

During the comparatively short period he spent as a field geologist, Holland turned out a remarkable volume of work on various geological problems, which included his well-known and classic work on the Charnockite series of Madras; the elæolite and corundum-syenites in South India; the mica-apatite-peridotite dykes of the Damodar valley coalfields; the mica deposits of India; corundum in South India; his recognition of the identity of bauxite and laterite, and his work on the stability of hill slopes in parts of the Himalaya. In 1908 he published a Sketch of the Mineral Resources of India.

New Appointments

In 1902 L. L. Fermor, G. E. Pilgrim and J. M. MacLaren joined the Survey. At the time of Holland's appointment as Director, there were 14 officers, of whom Fritz Noetling, P. N. Bose, R. D. Oldham and F. H. Smith, as well Hiralal and Kishen Singh, later retired or resigned. Several new officers were recruited, of whom G. H. Tipper (1903), H. Walker (1904), E. H. Pascoe (1905), K. A. K. Hallows (1905), G. de P. Cotter (1905), J. C. Brown (1905), H. C. Jones (1906), A. M. Heron (1906) and J. J. A. Page (1906) joined the Survey in the senior grade, and S. Sethu Rama Rau and M. Vinayak Rao in 1904 in the junior grade. In 1906 R. R. Simpson was transferred to the Department of Mines and J. M. MacLaren resigned. A special post of Chemist was created to which W. A. K. Christie was appointed in 1906. N. D. Daru and Murray Stuart joined in 1907 as geological officers in the senior grade. At the end of 1910 the number of officers, including the Chemist but excluding T. H. D. La Touche, who retired that year, was 18.

The Kangra Earthquake

On April 4, 1905, a devastating earthquake took place in

the Kangra Himalaya in Eastern Punjab. The earthquake was investigated by C. S. Middlemiss, R. R. Simpson, E. H. Pascoe and K. A. K. Hallows. Middlemiss gave a detailed account of the earthquake and located the main epicentre near Kangra, with a minor one running along the northern edge of the Dun, near Dehra. He attributed a depth of focus of 21-40 miles for this shock and pointed out that the two epicentral regions lay in embayments of Siwalik rocks within the main thrust front.

Surveys

A number of areas in India and Burma were geologically mapped during Holland's Directorship. C. S. Middlemiss carried out mapping in the Vizagapatam Hill Tracts where he came across a number of interesting rock types in association with charnockites and khondalities which he described in a petrological paper. Later Middlemiss was entrusted with the geological surveys in Rajputana and Central India, in which work he was assisted by H. Walker, A. M. Heron, S. Sethu Rama Rau and G. de P. Cotter. Middlemiss produced a detailed memoir of the Geology of Idar State which was published in 1921. In Central Provinces mapping of the Archæans as well as of some younger rocks was undertaken by P. N. Datta and L. L. Fermor, and resulted in the discovery of a large number of important deposits of manganese-ore. In Assam the south-eastern portion of the Khasi hills was mapped by P. N. Bose, while the auriferous river gravels in the Brahmaputra valley were examined by J. M. Maclaren. The latter, who came in place of F. H. Hatch, and had had experience of gold mining in Australia, made detailed surveys of gold deposits in several parts of Bihar, Hyderabad and Madras. The coal-deposits of the Naga hills in Assam were examined by R. R. Simpson. As a result of E. V. Vredenburg's work in Central India new light was thrown on the classification of the Vindhyan system. Vredenburg also wrote a valuable account of the diamond-bearing conglomerates of the Panna State. Accompanied by G. H. Tipper, he

examined the sulphur mines at Sanni in Baluchistan and worked out the stratigraphy of that area.

Burma

In Burma T. H. D. La Touche continued his investigations till 1907 and made an outstanding contribution to the geology of the Northern Shan States, where he worked out an unbroken succession of marine sediment ranging in age from Ordovician to Permo-Carboniferous and resting unconformably on a complex of Archæan gneisses, marbles and granites. La Touche was the first person to discover graptolites in Burma, which is the only place where they have been found in the former Indian Empire. The Palæozoic strata are unconformably overlain by marine Rhætic and Jurassic beds and the latter by fresh water Tertiary deposits, the fossils contained in which have been described by a number of foreign palæontologists. An account of La Touche's work in the Shan States is the subject of a classic memoir published in 1913. In his investigations La Touche was assisted first by P. N. Datta and later by G. E. Pilgrim and J. C. Brown. To P. N. Datta should be given the credit of the discovery of Devonian and Mesozoic beds of the Northern Shan States. R. R. Simpson, in collaboration with La Touche, as well as independently, studied several coalfields in Burma, and J. J. A. Page commenced his investigation of the occurrences of tin-ore in southern Burma, which he continued till 1913.

The Himalaya

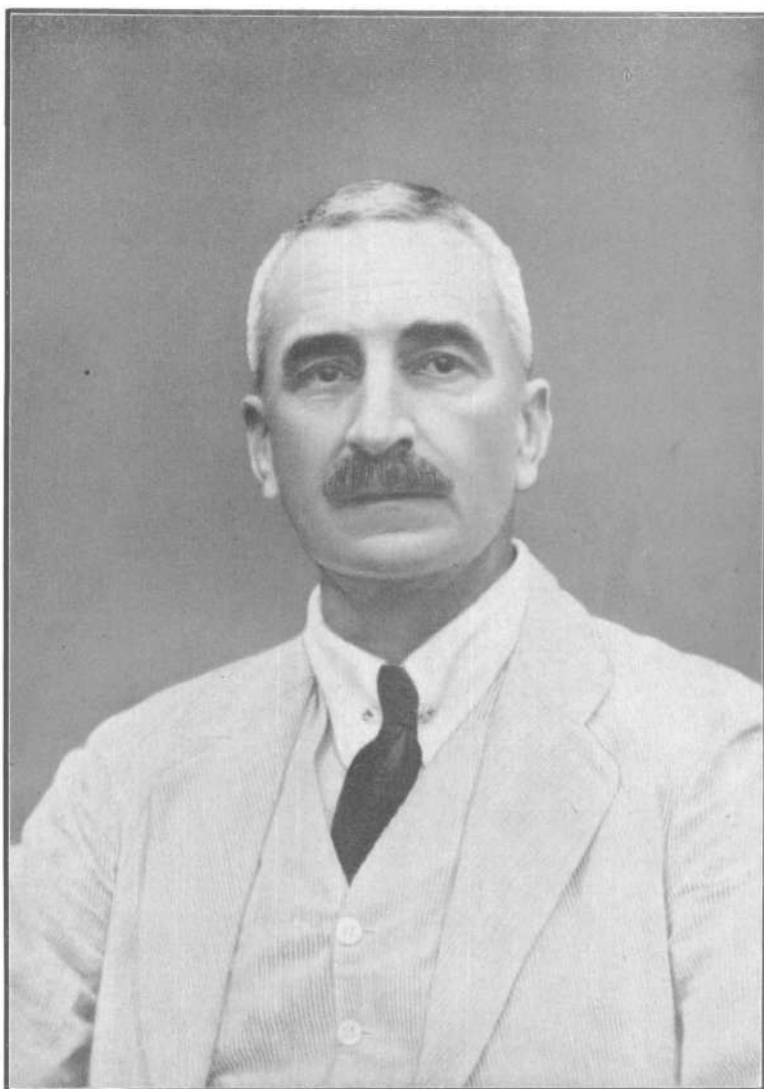
During the summer of 1903, R. D. Oldham surveyed parts of south-east Kashmir, when he studied the glaciation and physical history of the Indus valley. Oldham threw doubt on the lacustrine origin of the Karewas and considered them to be ordinary fluvial alluvium. By the end of the 19th century a considerable area of the Himalaya and related ranges had been examined. In 1901 Hayden began his detailed survey of the Tethys rocks of Spiti, and his memoir, published

in 1904, was devoted mainly to an account of the fossiliferous sequence extending from the Cambrian to the Cretaceous, which was shown to have been compressed into folds of the simplified Jura type as understood before the researches of Buxtorf. This work is of great value to the understanding of the stratigraphical and faunal succession but, because the structures actually exposed within the Spiti zone lack the elements characteristics of overthrust terrains, new conceptions regarding the structures of ranges were not developed. Hayden accompanied the Tibet Frontier Commission (popularly known as the Younghusband Expedition) to Lhasa and described the geology of an unexplored area in Tibet.

The period 1907-8 marks the end of a long succession of years devoted to the Himalaya, and saw the publication of the well-known "Sketch of the Geography and Geology of the Himalaya Mountains and Tibet" jointly by Burrard of Survey of India, and Hayden of the Geological Survey of India. The geological sections across the ranges show a series of faulted but essentially autochthonous crustal blocks, very different from the complexity of structure which was being found at that time in the Alps and the North-west Highlands of Scotland. The conception of the tectonic disposition of the outer ranges rested with that of the Main Boundary Faults, which had been developed by Middlemiss in 1890 and 1896 from the earlier views of H. B. Medlicott as a result of his studies of the Kumaon foot-hills and Hazara. The outer Himalaya were considered to be traversed by a series of faults originating from movements along subsiding shore lines that had delimited successive zones of sedimentary deposition. Section 6 of *Mém. Geol. Surv. Ind.*, XXIV (1890) shows a marked thrust fault with an inclination of 24° from the horizontal at the Jhar Gadh, but the implications of such strongly reversed faults were not discussed, and in his later memoir on Hazara (1896) Middlemiss used the term boundary fault beyond its legitimate palæogeographic definition even to indicate the separation of the slate zone from the crystalline and metamorphic zone.

Holland considered that the tillite in the Simla hills known as the Blaini Boulder Bed was of Cambrian age, and not Permo-Carboniferous as had been earlier suggested by R. D. Oldham. This revised correlation, later to be changed, placed the whole sequence of slates, phyllites, schists and quartzites below the Blaini as Pre-Cambrian. The exotic blocks of Mallar Johar presented a serious problem regarding provenance, and were interpreted by Von Krafft as due to large volcanic outbursts extending far from the sources of eruption.

Holland retired from the service of the Government of India in 1909 at the early age of 41 years to accept a Professorship of Geology at Manchester University. He came back to India a few years later as Chairman of the Indian Industrial Commission in 1916 and in 1919 was made a Member of the Viceroy's Executive Council, in charge of Industries and Commerce. While at Manchester, Holland assisted by G. H. Tipper, wrote a memoir on Indian Geological Terminology, which was first published in 1913 and did much to define the various stratigraphical and petrological names used in Indian geology. Holland finally retired from India in 1921 but remained an important figure in British Science. His advice was constantly drawn upon by the British Government and the Governments of other countries of the British Commonwealth. As is well known, he was for several years Rector of the Imperial College of Science and Technology, London and later Principal and Vice-Chancellor, Edinburgh University. At the same time Holland was President of various scientific and technical societies and was Vice-President of the Royal Society in 1924-25. His great interest in the progress of the Geological Survey of India and in matters relating to geological research in this country remained till his death on the 15th May, 1947.



H. H. HAYDEN

H. H. HAYDEN

1910-1921

H. H. Hayden succeeded Holland as Director in December, 1910. Hayden became well-known for his interest in mountain climbing and exploration of unknown regions, and his work on Himalayan, Tibetan and Afghan geology. He also travelled in the Chitral and Pamir regions and has left an excellent paper on the geology of these areas. The study of the Himalayan glaciers was initiated by Hayden, who, with La Touche and Coggin Brown, undertook surveys of the snouts of glaciers in the Karakoram, Kumaon and Sikkim. It was during Hayden's Directorship that the first World War took place, and he diverted the attention of the Department immediately to the development of the wolfram, mica and other strategic mining industries.

Surveys

Hayden followed Holland's policy of systematic mapping for mineral development and detailed his officers to various parts of India and Burma for the purpose. Two new recruits in 1911 were H. S. Bion and C. S. Fox, followed by R. C. Burton in 1912 and R. W. Palmer in 1913. In 1913, P. N. Datta retired and J. J. A. Page resigned. Assisted by Burton and Fox, Fermor commenced a detailed examination of the Archæans of portions of Central Provinces which continued over a long period in the course of which he introduced W. D. West, D. Bhattacharjee, and S. K. Chatterjee to the area to unravel its complicated geology. Fermor also studied the Deccan trap flows in Central Provinces. Pilgrim made an expedition to Bhutan and later surveyed portions of Persia and Arabia where he laid down the succession of formations in Persia from Pre-Cambrian to Recent, introducing a nomenclature that has in the main been adopted by later

workers. In Bahrein Island in the Persian Gulf he mapped a dome that led later to boring for oil. He also undertook a systematic and exhaustive study of the fresh water Siwalik deposits (Tertiary) of north-western India, Perim Island and Baluchistan. With the help of the fossilised mammalian remains in these beds Pilgrim was able to divide the Siwalik system into three broad divisions, which he correlated with the Middle Miocene, Lower Pliocene and Upper Pliocene of Europe. Pilgrim's study of the drainage during the middle Tertiary times in northern India brought about the conception of the Siwalik river or Indobrahm as it was termed by E. H. Pascoe.

For many years Vredenburg worked on the Tertiary marine fossils collected by himself and other workers in Baluchistan, Sind and Burma, and succeeded in revising the classification of the Tertiary formations of northern India. He published a number of valuable Palæontological papers and monographs dealing with Tertiary mollusca, and assigned the marine Tertiary fauna of north-western India to the Indo-Pacific life province. Soon after Pascoe became Director, Vredenburg, who was broken down in health, went on long leave and died in London on March 12, 1923, surrounded with fossils.

The revision of the old geological map of the Raniganj coalfield was completed by H. Walker, who added to our knowledge of the underground correlation of the coal seams and also accurately mapped the numerous faults and dykes in that field. At a later date Cotter attempted a revised classification of the Gondwana system which still holds good. A comprehensive monograph on the coalfields of India was published by R. R. Simpson in 1913 and in 1919 C. S. Fox was entrusted with a survey of the bauxite occurrences of India. A survey of the iron-ore resources of Bihar and Orissa was begun by H. C. Jones and continued for several years, in which work M. S. Krishnan took part at a later date. The systematic mapping of Rajputana (Rajasthan) commenced by Heron in Holland's time was continued and, after an interrup-

tion caused by transfer of Heron to Burma during the period of the Great War of 1914-18, it was resumed by him at a later date.

Oil

Between 1905-15 Pascoe was engaged in a survey of the oil resources of Burma, Assam, Punjab and the North-West Frontier Province. In 1913 he was sent to the Persian Gulf, the Arabian Coast and West Persia and accompanied the Slade Oilfields Commission in the Persian Gulf in 1913-14. Pascoe soon became a recognised authority on the geology of petroleum. His researches on the petroleum occurrences of Burma, India and Mesopotamia were the subject of four comprehensive memoirs, in which he discussed the genesis and mode of occurrence of oil along with a detailed description of the geology of the oilfields and their structural features, and in twelve other papers in the *Records* of the Geological Survey of India. In one of the latter Pascoe directs attention to a structural feature of fundamental importance to the study of the oilfield in which the folding is asymmetrical, and also to the estimation of the value and prospects of an oilfield. He also accompanied an expedition to the unknown regions of the Naga hills, and made important contributions to the physiography of the submontane tracts of the Himalaya in late Tertiary times.

Burma

During Hayden's Directorship, Cotter was able to make important contribution to the history of Tertiary deposition in Burma, and to prove that a typical geosynclinal lay between the Shan plateau and the Arakan Yoma in Tertiary times, and that fluvial sediments and deltaic deposits pushed the sea before them while at the same time the area of subsidence kept shifting to the south. Cotter will be remembered for his work on the geotectonics of the Tertiary Irrawaddy basin and the Pegu and Eocene succession in the Minbu district, where he laid the foundation

for all subsequent stratigraphical work on the rocks of the main Tertiary basin of Burma. Sethu Rama Rau worked indefatigably for several years to unravel the geology of the Mergui district in Burma, and an account of this was published in 1930 after his death in 1929 while he was still on active service. The geology of the northern portion of the Mergui Archipelago was described by Coggin Brown and A. M. Heron in 1923. For a couple of years Coggin Brown was deputed to Yunan in Eastern China for Natural History Explorations and he published an interesting account of some Pre-Cambrian, Palæozoic and Mesozoic of this somewhat unknown area in a series of papers in the *Records*. Previously in 1911 Brown accompanied an expedition to the Abor hills through the Dihong valley in the Assam Himalaya and found that Gondwana beds were overlain by slate, mica-schist and dolomite in the Darjeeling Himalaya. Brown also came across some volcanic rocks in the Abor hills.

Publications

A revised geological map of India, incorporating the results of mapping up to 1910, was published by Hayden in 1911 on a scale 1" = 32 miles. The voluminous mass of information, relating to the occurrences of economic minerals in India scattered in the departmental publications and other scientific journals, was laboriously collected by La Touche and published in a single volume in 1918, entitled 'Index of Minerals of Economic Value'. In the previous year a comprehensive bibliography of Indian geology had been published by the same author. The Srimangal Earthquake of 1918 was described by Murray Stewart, while R. D. Oldham made a critical study of the records of the Great Kutch earthquake of 1819, from which it became evident that the shock was one of the largest which India has suffered.

World War I

During the first World War the Survey was disorganised by several officers joining the Forces, but the situation was

retrieved by recalling the officers later for investigation of minerals required for war purposes, especially tin and tungsten. Coggin Brown and Heron made extensive tours in the Tavoy district in Burma and the specimens were chemically analysed in the field by Mahadeo Ram. A useful account of tin-tungsten mineralisation together with a description of the geology and ore deposits of that district was given in a joint memoir by Brown and Heron. The Indian Munitions Board employed L. L. Fermor as its Mineral Adviser, and C. S. Fox was placed in charge of the so-called Mashodih Government Mica Mines at Jorasemar, on the edge of the Kodarma forest in Bihar, where he remained till the armistice. Meanwhile the Survey had lost several officers. Bion died of appendicitis in June, 1915; Burton died of wounds in Mesopotamia in April, 1916; Middlemiss retired in April, 1917 and Daru died in September, 1918. After keeping the vacancies in abeyance for some time, two of them were filled by the promotion of Sethu Rama Rau and Vinayak Rao to the senior grade in September, 1919. The expansion of the Geological Survey of India sanctioned earlier was implemented in 1920, and in the same year H. Crookshank, C. T. Teychenne and E. L. G. Clegg were appointed. In 1921, D. N. Wadia, G. V. Hobson, F. W. Walker and J. A. Dunn joined the department, but in October, 1921 Murray Stuart resigned. During his Directorship, Hayden succeeded in effecting an increase of the cadre of the Geological Survey of India and an improvement in the emoluments of the various posts. He retired from the Survey in June, 1921, after nominating E. H. Pascoe as his successor as Director. Hayden was elected a Fellow of the Royal Society in 1915, and died in 1923 from a rock fall while climbing on the Finsteraarhorn in Switzerland.

E. H. PASCOE

1921—1932

Pascoe became Director during the post-war coal 'boom', at a time when trade enquiries were brisk and 'mushroom' industries were much in evidence. He had long ago made a name for himself by his excellent work in connection with the petroleum resources of India and Burma, and, during the War, in Irak on behalf of Government. He followed a policy of caution and restraint in advising Government on mineral matters as also in matters of recruitment for new appointments in the expanded Survey. As the advisory work in the tin and wolfram areas of Tavoy was over, Coggin Brown was sent to London in 1919 to act as Mineral Adviser in the newly started Imperial Mineral Resources Bureau, where he remained till 1921, when he was relieved of that work by Fox, who continued in that capacity in London till 1923, when the post was abolished on the plea of economy. Later it was found necessary to re-establish this post as a part of the personnel of the High Commissioner for India in London and G. H. Tipper, after his retirement from the Survey, became the Mineral Adviser in London from 1929 to 1946. A number of special brochures, giving a comprehensive review of the occurrences, uses and marketing of minerals of economic importance, were published in the series of Bulletins of Indian Industries and Labour, contributions to which were made by officers of the Department.

New Appointments

Meanwhile the sanctioned cadre of the Geological Survey of India was completed by the recruitment in the senior grade of A. L. Coulson in 1922, and E. J. Bradshaw, C. T. Barber, E. R. Gee, W. D. West and A. K. Banerji in 1923, and in the junior grade of B. B. Gupta and D. Bhattacharji in 1921, and B. C. Gupta, H. M. Lahiri and L. A. N. Iyer in



E. H. PASCOE

1922 and P. N. Mukherji in 1924. It was during Pascoe's time that the department attained the full sanctioned strength of 36 officers, and the foundation was laid for the Indianisation of the service. As a consequence of the death of E. V. Vredenburg in 1923, the resignation of C. T. Teychenne in the same year, the fatal accident to F. W. Walker, who was gored to death by a bison while he was engaged in field work in the jungles of Burma in 1925, the retirements of Hallows in 1926, H. Walker in 1927, Tipper in 1929, and Pilgrim in 1930 and the death of Sethu Rama Rau in 1929, a number of posts fell vacant and were filled up by the appointments of M. S. Krishnan in 1924, P. Leicester and S. K. Chatterjee in 1925, J. B. Auden, V. P. Sondhi and H. L. Chibber in 1926, B. B. Gupta in 1926 (promoted), and P. K. Ghosh and M. R. Sahni in October, 1929.

Tipper died on the 23rd April, 1947. His work on the monazite deposits of Travancore and of samarskite deposits of Nellore provided the background of our knowledge of rare earth or radio-active minerals in India. He also reported on the geology and mineral resources of Chitral and on the geology of the Andaman and Nicobar Islands. A man of genial temperament, Tipper was fortunate in possessing a retentive memory, which enabled him to play the role of a walking encyclopædia in the Department.

As facilities for advanced studies in geology were lacking in the country, young Indian officers in the junior grade were encouraged to proceed to the Imperial College of Science and Technology, London, for a thorough grounding in the subject before their promotion to the senior grade. Several officers including A. K. Banerji, L. A. N. Iyer, A. M. N. Ghosh and A. K. Dey were granted study leave for the purpose, but the promotion of the last three officers to the senior grade was considerably delayed by the drastic retrenchment of the cadre in 1932. In addition to recruiting an appreciable number of young Indians with suitable qualifications in geology, scholarships were given to Indian students for study on scientific and industrial subjects in

Europe. In the planning and founding of the Indian School of Mines (now known as the Indian School of Mines and Applied Geology), Dhanbad, Pascoe took a leading part and the school was finally opened in 1927, with Pascoe as the President of the Governing Body of the school.

Coal Survey

With an increased strength of officers Pascoe increased the number of field parties from three to six, and allotted an increased number of men to Burma. The survey of the coalfields of India had been one of the primary tasks of the Geological Survey of India in its early days, when the topographical maps were very inferior as compared with the results of modern surveys. The commercial development of many of these fields had rendered urgent their re-survey geologically on modern maps, where these existed, both in order to help the mining industry, and also because it had become necessary to estimate what proportion of India's coal reserves could be regarded as of superior quality, since Government policy with reference to the mining industry depended fundamentally upon such knowledge. It was also foreseen that, with the passage of time, increasing demand on the reserves of India's metallurgical coal would be made by the country's growing steel industry. In consequence, Pascoe formed for the purpose a coalfields party for detailed surveys of the Jharia and Raniganj coalfields on a scale of 4" = 1 mile, as also a general survey of all the coalfields in India by C. S. Fox, who was assisted by Sethu Rama Rau, J. A. Dunn, E. R. Gee, A. K. Banerji, J. B. Auden and A. K. Dey. The work lasted from 1925 till 1929. The results of these survey are represented by a series of *Memoirs* mainly by C. S. Fox, with one by E. R. Gee.

The Salt Range

In order to determine conclusively the age of the Saline series that underlies the Cambrian rocks of the Salt range in

the western Punjab, Pascoe selected Gee for a detailed survey of the area with the help of modern topographical maps enlarged to a scale of 2"=1 mile. Wynne, who originally mapped the Salt range in the seventies of the last century, concluded that this series was in its normal position and therefore was of early Cambrian age or older. Later Middlemiss thought that the salt might be of intrusive origin, and Pascoe, as a result of his studies in the Punjab, came to the conclusion that the salt and the salt marl were of Tertiary age and that the position of the Saline series below the Cambrian and other Palæozoic rocks of the Salt range was due to an extensive overthrust from the north. Pascoe's views were accepted as a possibility by Holland and Hayden. In the course of his field work Gee showed that the boundary between the Punjab Saline series and the overlying Talchirs over a distance of several miles in the central and western portions of the range is an undisturbed sedimentary one, proving that the Saline series is older than the Pre-Talchir unconformity and is of Lower Cambrian or Upper Pre-Cambrian age. The age of the Saline series has not been finally settled, as some geologists, including the late Prof. B. Sahni, the palæobotanist, have brought forward perplexing palæontological evidence to support a Tertiary age. Some doubts have been cast on Sahni's conclusions due to the finding of similar fragmentary plant fossils in beds of undoubted Cambrian age, and the final solution of the problem of the age of the Saline series, therefore, still remains to be settled.

Mapping in the Potwar plateau, Kala Chitta hills and other parts of the Punjab and the North-West Frontier was undertaken by Cotter, Wadia, Coulson, Lahiri and P. N. Mukherji. Later, in 1933, Cotter published a *Memoir* on a portion of the ~~Attock~~ district, in which he incorporated the work of Lahiri and Mukherji and discussed the geological and structural features of the Kala Chitta hills. He studied the erratic blocks north and south of the Kala Chitta range, and considered that the erratics were mud avalanches arising from

the Hazara mountains at a time when the climate was colder and the glaciers had a wider extent.

The Himalaya

Except for work carried out by Middlemiss as Director of the Mineral Survey of Kashmir after his retirement from the Geological Survey of India, mapping in the Himalaya suffered a break of 18 years before it was taken up again by Pilgrim, Wadia, West, Auden and Lahiri between 1925 and 1939. Fortified by the progress of tectonic and metamorphic research abroad, these workers soon found clear evidence of major thrust movements and reversals of metamorphic zones in the Kashmir, Simla, Mussoorie, Garhwal and Nepal-Sikkim Himalaya, and had greatly to modify the earlier conception of main boundary faults. Pilgrim and West described the overthrusts and inversions in the Simla area, while D. N. Wadia mapped the overthrusts of Poonch, pointing out that the thrust separating the Eocene from the overlying Dogra Slates was more than a mere boundary fault. In the sub-Himalayan region of the East Punjab, Lahiri found evidence of thrust movements in late Pleistocene times, causing the Siwalik beds to override the Older Alluvium and *dun* gravels at some places. In a well-known paper on the Syntaxis of the North-West Himalaya Wadia showed that there were no grounds for supposing that the two mountain systems of the Himalaya and the Hindu Kush originated through the union of two distinct systems of disturbances, as had been suggested by Suess. Wadia considered the Kashmir re-entrant to be a fold-virgation in which the different stratigraphical groups and fold-systems were bent round a central projecting tongue of the Indian peninsula. Wadia's work showed the existence of extensive thrust planes between the Salkhala series and the underlying Trias and Panjal traps on both sides of the re-entrant. Continuing his researches up to the Nanga Parbat *massif* he indicated that the mountain is composed of a core of biotite-gneiss surrounded by Pre-Cambrian Salkhala rocks with varied degrees of gneissic injection.

The Peninsula Archæan

In the Archæan terrains of Peninsular India detailed mapping was resumed in Central Provinces (Madhya Pradesh) and Rajputana (Rajasthan) where work had to be suspended during the war period. In the former area Crookshank and West were placed under Fermor, and in the latter Coulson, Bradshaw, Chatterji, P. K. Ghosh, Iyer and B. C. Gupta under Heron.

In Bihar and Orissa, H. C. Jones continued his surveys in the iron-ore belt of Singhbhum district, Bonai and Keonjhar, where he spent nearly 17 years of his career. In a memoir he has briefly described the geology of the area and made an estimate of the reserves of iron-ore within the belt. In his opinion the ores were formed in the main by the local leaching out of silica from the regionally distributed banded hematite-quartzites. Jones had a genial personality and his geological photographs are amongst the best in the Survey's collection. Krishnan was first placed under Jones for a while and later entrusted with the mapping of Gangpur State in Orissa. In Singhbhum Dunn began a survey of the copper belt and also other parts of the district. Dunn was also detailed for an investigation of the kyanite, sillimanite and corundum deposits in Assam, Bihar and Rewa in Vindhya Pradesh, and published the results of his investigations in the form of a memoir.

Assam and Burma

A portion of the unsurveyed tracts in the Khasi hills, Assam was mapped by Palmer, who died of illness soon after his return from Assam in 1922. In Burma, Vinayak Rao, F. W. Walker, E. L. G. Clegg and B. B. Gupta carried out systematic mapping in Mergui, Tavoy, Amherst, Minbu and Pakokku districts with G. de P. Cotter in charge at first and under J. C. Brown afterwards, when the strength of the Burma party was reinforced by the addition of C. T. Barber, A. K. Banerji, P. Leicester, H. L. Chibber, V. P. Sondhi and M. R. Sahni, and Sethu Rama Rau for a short period. Sondhi

carried out an interesting investigation of late Tertiary vulcanicity, including a study of the explosion craters in Upper Burma. M. R. Sahni continued the work of La Touche in the Shan States and discovered a unique assemblage of Permian and Mesozoic ammonites, gastropods and lamellibranchs in the Plateau Limestone. Clegg continued the mapping of the early workers in the Minbu district, and Vinayak Rao and Leicester in the Mergui district. Cotter and F. W. Walker surveyed the Loi-an coalfield near Kalaw in the Southern Shan States. H. L. Chibber commenced the survey of the Jade mines area in the Myitkyina district in Upper Burma and described a variety of igneous rocks which had been intruded into the Tertiaries. The most interesting feature of this region lies in the preservation of the record of several periods of igneous activity dating from post-Permo-Carboniferous up to sub-Recent times. In 1929 Brown and Banerji began a large scale geological mapping of the Mogok Stone Tract and divided the Archæan rocks into a number of stages, which were mapped separately. This work was continued by Clegg and L. A. N. Iyer. Coggin Brown studied the Pyu earthquakes of 3rd and 4th December, 1930, and subsequent Burma earthquakes up to January, 1932, and delineated a well-defined seismic zone, aligned (N.-S.), in the Tertiary belt of Burma.

It was Pascoe, who introduced the system of placing an officer of the department as Resident Geologist in the oil-fields of Burma for day to day contact with the progress of the investigations and development work in the oilfields. C. T. Barber was the first Resident Geologist at Yenangaung appointed by Government.

Other Investigations

The Department also attended to numerous mineral enquiries the number of which considerably increased in the post-war years, and in addition, numerous problems of water-supply, sites of irrigation or storage dams, landslips, road and railway alignments in hilly regions and other matters relating to engineering geology were dealt with more and more as

years passed. A departmental geologist, A. M. Heron, was attached to the first Mount Everest expedition, and the services of Vinayak Rao, D. Bhattacharji and P. N. Mukherji were placed at the disposal of C. A. Matley for collecting, from Trichinopoly and the Lameta beds of the C. P. the fossil remains of the extremely diversified order of the Mesozoic reptiles known as Dinosauria. Since 1920 our knowledge of the Indian variety of this interesting reptile has greatly increased by the finds of Matley and their study by Prof. Von. Heune, of Tübingen, Germany. It was found that the dinosaurian remains of the C. P. show close affinities with those discovered in Madagascar, Patagonia and Brazil, indicating the existence of land bridges between India and these countries across the Indian and Atlantic oceans or, in other words, the persistence of the remnants of the old Gondwana continent in Cretaceous times.

Vertebrate Palæontology

During 1921-29, Pilgrim was mostly engaged in the study of the mammalian remains from the fluviatile Siwalik deposits of north-west India and also from the fresh water Tertiaries of Burma, and thus continued the work of the two pioneers Falconer and Cautley who produced the well-known monograph "The Fauna Antiqua Sivalensis", and that of Richard Lydekker. With the help of Vinayak Rao, D. N. Wadia, H. M. Lahiri, N. K. N. Aiyengar, G. de P. Cotter and B. B. Gupta, Pilgrim added largely to the already large collections of Siwalik mammalian fossils in the Geological Museum in Calcutta, and he thus had at his disposal an immense mass of material to which he devoted all available time, barring the the period spent in mapping the Simla hills with West in company. He continued his palæontological researches in London at the Natural History Museum after his retirement. The total result is an impressive series of fine memoirs in the *Palæontologica Indica* descriptive of various groups of Indian vertebrates, of which one may list in chronological order the

Giraffidae of India, the Vertebrata of the Gaj of the Bugti hills and the Punjab, the Perissodactyla of the Burma Eocene, the Suidae of India, the Artiodactyla of Burma, the Carnivora of India and finally the Bovidae of India. He was also requested to write on the fossil Bovidae collected by the American Museum of Natural History. Separate mention may be made of Pilgrim's discoveries of fossil primates in the Siwaliks, comprising no less than five new species and two new genera. In his view *Sivapithecus*, one of these latter, was, when he wrote (1915), the closest anthropoid phylogenetically to man, with the possible exception of *Pithecanthropus* and *Eoanthropus*.

Pilgrim left India for good in 1930. On the day he was to retire from India he was still carrying out research; but an importunate crow, deceived by the verisimilitude of a fossil tooth with a more palatable morsel, removed it from his table. His farewell words to his assistant were "Aiyengar, do please search for that tooth", for it was a critical one for a particular identification, and Pilgrim's concern was more over the truth thus wantonly concealed than with the prospects of a final voyage to a superannuated retreat. He was elected, very belatedly, a Fellow of the Royal Society of London in 1943, but died soon afterwards in the same year. With his death vertebrate palæontology lost one of its most distinguished exponents, and the world's greatest authority on the rich Siwalik fauna of India.

Publications

Before he left India Pascoe had the official Geological Map of India, compiled in 1911 by Hayden, brought up-to-date. The revised map was published in 1932 on a scale 1"=32 miles, and incorporated the surveys during the intervening period. During this period (1921-30) a large number of publications were issued, of which the more important ones, in chronological order, were: The bauxite and aluminous laterite occurrences of India by Fox; two memoirs by Vredenburg

on the Cephalopoda, Gastropoda and Lamellibranchiata from the post-Eocene Tertiary formations of North-Western India; Wadia's Geology of Poonch State (Kashmir); Jowett's Karanpura coalfields; Dunn's Aluminous refractory materials in Northern India; Pilgrim and West's Structure of the Simla hills; Sethu Rama Rau's Geology of the Mergui district; and Fox's Jharia coalfield. A large number of short papers of geological interest were published in the *Records* of which mention may be made of Fermor's Mineral Resources of the Central Provinces and his Mineral Resources of Bihar and Orissa; H. C. Jones's Account of the iron-ores of Singhbhum and Orissa; Heron's Geological results of the Mount Everest reconnaissance; Murray Stuart's Geological account of a traverse from Assam to Myitkyina through the Hukong valley and to the Chinese Frontier; Matley's Cretaceous Dinosaurs of the Trichinopoly district; Mason's Glaciers of the Karakoram and neighbourhood and Wadia's Syntaxis of the North-West Himalaya. Quite a number of monographs on invertebrate and vertebrate fossils from different parts of India were issued in the *Palæontologia Indica*.

Pascoe left India for good in 1930 and retired from the service in 1932. After his retirement he was engaged in the preparation of a revised edition of the Manual of the Geology of India in four volumes. The first volume of this work, which was published just after his death on July 7, 1949, is a monument to his love for work, thoroughness in mastering details and an encyclopaedic knowledge of the subject. The remaining volumes, when published, will be of enduring value to all students of Indian Geology.

L. L. FERMOR

1932—1935

On the 13th April, 1930 Pascoe handed over charge of the office of Director to L. L. Fermor and left India on long leave preparatory to retirement. The end of the decade was marked by a great business depression, and Fermor was still officiating when, early in 1932, the Government of India considered the financial position justified a general retrenchment in the cadre of all the Civil Services and a 'cut' in all salaries. In consequence, when Pascoe's retirement became effective on the 6th April, 1932, and Fermor became Director, the Geological Survey of India had lost the services of several valuable officers namely, Cotter, Brown, Jones, Banerji, Leicester, Chatterjee, B. B. Gupta, the experienced Chemist W. A. K. Christie, and the Artist K. F. Watkinson. Subsequently Hobson accepted the voluntary conditions of retrenchment and at a still later date Barber and Chibber resigned in 1935. The losses might have been greater but for the expedient of 'demoting' some of the younger officers from the senior to the junior grade and keeping them there pending vacancies for their promotion. The harmful effects of this drastic retrenchment of the personnel of the Survey were felt later at the time of the second World War.

When Fermor became Director he had already established a secure place for himself in the mining and geological world by his outstanding work in connection with the description of the manganese-ore deposits of India and the discussion of their genesis and relationship to the Archæan rocks containing them. A petrologist of a high order Fermor had discovered and described a number of new manganese minerals. His researches on the Pre-Cambrian metamorphic rocks of India had earned him worldwide recognition and his name was a household word to every student of Indian geology. His



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conception of an infra-plutonic zone supplied a basis for deductions regarding the internal conditions of the earth. His was the first contribution in the Department on the study of polished sections of ores in reflected light and he was the first to make use of the magnetic needle for the prospecting of the ores of iron and manganese. His deductions from a structural study of the manganese-ore belt of the C. P. elucidated the behaviour of the ore-bodies and their location at depth. His researches on the specific gravity and proximate composition of some Indian durains are still regarded as important contributions to modern research on coal.

Though the Survey was depleted of its former strength in Fermor's time, it carried on, to the best of its ability, the work which was started prior to retrenchment. The number of field parties had to be reduced from six to three. In order to fill up some blank patches in the geological map of India, Fermor employed H. Crookshank and P. K. Ghosh for systematic mapping in Bastar, Central Provinces; M. S. Krishnan in Gangpur, Orissa; A. M. N. Ghosh in the Khasi hills, Assam; and A. K. Dey in Jashpur, C. P. At headquarters D. N. Wadia was appointed Palæontologist and the numerous chemical analyses were attended to by P. C. Roy and Mahadeo Ram, both of whom had previously received sound training at the hands of W. A. K. Christie, the Chemist.

Christie served the Survey as Chemist for 26 years and took part with Holland in the study of the origin of the salt deposits of Rajputana. Christie was of the opinion that the salinity of the salt lakes in Rajputana (Rajasthan) was due to wind-blown salt deposited in desert basins. He subscribed to Middlemiss's views that the salt deposits of the Cis-Indus Salt range were the result of igneous action, paying particular attention to the occurrence of potash salts. Christie had a critical mind as sharp as the edge of a razor, and was able immediately, with grace and wit, to correct the weak points in the researches of his junior colleagues.

An earthquake, which took place on the 3rd July, 1930,

with Dhubri within the epicentral tract, was studied by Gee and Krishnan and was published in the form of a memoir under the authorship of Gee. Geological mapping of the Salt range was also continued by Gee, and he and A. M. N. Ghosh made large collections of marine fossils from the Palæozoic and Triassic beds from various parts of the range. In 1932 and again in 1935-36, the Geological Survey co-operated with the Yale University and Yale-Cambridge expeditions by placing the services of A. M. N. Ghosh and N. K. N. Aiyengar at the disposal of the leader, Helmut de Terra, and made large collections of invertebrate Permo-Carboniferous, Permian and Triassic fossils from the Salt range and of fossil mammalian remains from the Siwalik deposits of the Punjab and of the Kashmir and Jammu Himalaya. From a study of the Pleistocene glacial and interglacial deposits of the Pir Panjal and neighbourhood, de Terra correlated the Upper Siwalik Boulder Conglomerate as equivalent to the second interglacial deposits. Fossil evidence disclosed that the last uplift of the Pir Panjal took place after the advent of early man and that the present desert conditions in Baluchistan and Sind came to pass well after 3000 B. C., probably some time about 1500 B.C.

In the sub-Himalayan region of the eastern Punjab, Lahiri continued the systematic mapping of the Siwalik and older rocks, and Auden described the thrust structure of the Krol belt between Solan and Mussoorie, which was followed by a paper on traverses in the Himalaya and one on the structure of the Garhwal Himalaya.

Rajputana

During Fermor's Directorship Heron was able to complete his surveys of Rajputana (Rajasthan), a task which was spread over a period of 27 years of steady mapping over an area of nearly 25,000 square miles. Heron found the oldest rocks of the Rajputana Archæans to consist of a Banded Gneissic Complex of metamorphosed sediments greatly injected

by both acid and basic rocks, and a gneissose granite termed the Bundelkhand gneiss. The basement rocks were unconformably overlain by two or three systems of sedimentary Archæans, each characterised by a conglomerate at the base indicating unconformable relationship. The oldest of these, known as the Aravalli system, had suffered little or no metamorphism, and was overlain first by the Raialo series and next by the Delhi system. A peculiar feature is that the Delhi rocks, which occupy the centre of a synclorium, are considerably folded and more highly metamorphosed than the older Aravalli rocks coming on the flanks. The Delhi system according to Heron was to be correlated with the Cuddapah system of South India, but differed from it in having been intruded by the Malani system of acid and some basic igneous rocks, including the Erinpura and Idar granites and the Malani rhyolite. These igneous rocks have been studied and described in detail by A. L. Coulson in his account of the geology of Sirohi State. In a memoir on Central Mewar, B. C. Gupta has given a detailed description of the Banded Gneissic Complex and of the Bundelkhand gneiss.

The Archæan rocks of Central Provinces

After working for a number of years on the Archæan rocks of the Nagpur, Bhandara and Chhindwara districts of Central Provinces, Fermor produced a detailed map of a complex of highly metamorphosed calcareous and argillaceous sediments with igneous intrusions which he grouped under the name of the Sausar series. The rocks consist of banded calcitic rocks, impure marbles, large bodies of manganese-ore of various types, quartzites, various types of schists and metamorphosed lava flows. They have been divided up into a number of stages which have a remarkable constancy over the area in which they have so far been mapped. In addition to the metamorphosed sedimentary rocks, there are a variety of porphyritic and fine grained granites, pegmatites and ortho-

gneisses which are younger than the Sausar series, and an injection gneiss which has gone by the general name of 'streaky gneiss'. A less metamorphosed group of Archaean sediments, perhaps an upward continuation of the Sausar series and designated as the Sakoli series, was considered by S. K. Chatterjee to have been formed as a result of retrograde metamorphism. W. D. West brought forward evidence to show the complexity of folding present in the rocks of the Sausar series, having mapped a *nappe* structure at Deolapar, near Nagpur, whereby different facies of the series, originally deposited far apart, had been brought into juxtaposition.

In Singhbhum, J. A. Dunn studied the Iron-ore series, named by H. C. Jones to include a suite of metamorphosed sediments and basic lavas, of which the banded hematite-quartzite is the most important member on account of its containing large deposits of high grade iron-ore, mostly hematite. In South Singhbhum the Iron-ore series is little metamorphosed or disturbed; but northwards both the metamorphism and folding increase, until in North Singhbhum the rocks are highly metamorphosed and severely folded. Although Jones had previously considered the Iron-ore series partly on account of its little metamorphism in South Singhbhum and partly on account of the fact that it rests unconformably on older metamorphic rocks, as likely to be of Cuddapah age and so younger than the underlying metamorphic rocks, Dunn included both of them under one system. The chief reason Dunn put forward for supposing them to be older than Cuddapah was that they are intruded by gneissic granites which are themselves intruded by dolerites, in place metamorphosed to epidiorites. And since no intrusions of dolerites have been known in Peninsular India between Cuddapah and Jurassic times, Dunn concluded that the Iron-ore series, the granites, the dolerites, and the folding and metamorphism were all older than Cuddapah, and therefore Archæan in age. The granite-gneiss and the various granites in Singhbhum have been studied in detail by Dunn, L. A. N. Iyer and A. K. Dey who worked together in that area for several years.

Other Surveys

In the Satpura range around Pachmari in Central Provinces, Crookshank mapped an area of Gondwana rocks and made critical observations regarding the passage of intrusive feeder sills into lava flows.

In South India, A. L. Coulson and P. N. Mukherjee studied the barytes and asbestos deposits in the Ceded districts of Madras, and Coulson published a couple of memoirs in this connection. In Assam, C. S. Fox commenced an investigation of the Tertiary coal deposits, laying special attention to the revision, on modern topo sheets, of La Touche's mapping of the Garo hills' coalfield. In 1933 A. M. N. Ghosh's services were placed at the disposal of C. A. Matley, leader of the Percy Sladen Trust expedition when an extensive tour of the Central Provinces was made along the outcrops of the Lameta beds of that State as a result of which a large collection was made, at Jubbulpore, of fossilised remains of the extinct order of reptile known as Dinosauria. Later Ghosh accompanied a punitive expedition to the unexplored areas of the Dibong valley in the Mishmi hills of the Assam Himalaya and reported a variety of schistose and gneissose rocks overlying Tertiary sandstones.

The Bihar and Baluchistan Earthquake

The Bihar-Nepal earthquake of the 15th January, 1934, which devastated large tracts of the Gangetic plain of Bihar and parts of the Katmandu basin in Nepal, was described by D. N. Wadia, J. A. Dunn, J. B. Auden and A. M. N. Ghosh. Damage to structures in the deep alluvial zone took place by slumping into the ground, whereas in the bordering regions closer to rock outcrops it was by shattering and collapse. The worst emissions of sand along vents and fissures took place in this slump belt, which had an area of 4,700 square miles. The postulated main line of failure took place in North Bihar below more than 6,000 feet of alluvium. Dunn considered it possible

that the narrow zones of higher isoseismals lying in lower isoseismals south of the main rupture were due to shearing along subsidiary fractures parallel to the main one. The authors prepared a seismic map of India and put forward recommendations regarding a building code.

W. D. West described the severe earthquakes of Mach on August 25th and 27th, 1931, and of Quetta on May 31, 1935, both in Baluchistan, and showed how the 15 shocks which had affected Baluchistan since 1852 were clustered mainly around the fold deflections of the Quetta re-entrant. Catastrophic though the Quetta shock was, with a loss of 25,000 lives, its instrumental magnitude was 7.3 as compared with 8.2 for the Bihar-Nepal shock, and its focus was shallow, being under 10 kilometres. It was shown that the major damage was incurred by buildings located on damp alluvium, whereas those on the drier alluvium to the north escaped the worst destruction. Using the results of the observations of the earlier workers, West prepared an isoseismal map of India broadly defining the various seismic belts of different intensities.

In Burma, Clegg continued the mapping of the Mogok Stone Tract that had been commenced in pre-retrenchment days by Coggin Brown and A. K. Banerji. Clegg was joined at a later date by L. A. N. Iyer. Bradshaw assumed charge of the duties of the Resident Geologist and Official Member, Yenangyaung and Singu Oilfield Advisory Boards at Yenangyaung. V. P. Sondhi continued his work in the Northern and M. R. Sahni in the Southern States.

At headquarters W. D. West studied the sequence of Deccan trap lavas disclosed by deep borings for water in Kathiawar (Saurashtra) and indicated that the various types of oceanite, ankaramite, limburgite and normal plateau basalt were extruded, without regard to order, from magmas which must have been available for tapping throughout the eruptive period. The primitive parent magma is considered already to have undergone differentiation before Cretaceous times into ultra-basic and normal types.

Publications

Of the few *Memoirs* that were published between 1931 and 1935, the more noteworthy were those by Fox on the Gondwana system and on the Lower Gondwana coalfields of India; Gee's Geology and coal resources of the Raniganj coalfield; Auden's Vindhyan sedimentation in the Son valley; and Jones's Iron-ore deposits of Bihar and Orissa. Of papers in the *Records* mention may be made of Coggin Brown and Sondhi's Geological account of a reconnaissance in the southern Shan States; Auden's Geology of the Krol Belt; Auden and Ghosh's Preliminary account of the Bihar-Nepal earthquake of January 15, 1934; Auden's Traverses in the Himalaya; and West's Account of the Baluchistan earthquake of May 31, 1935.

After a service of 33 years Fermor retired on the 7th November, 1935. The series of publications on the correlation of the Archæan formations in various parts of India, which he wrote before and after his retirement, testified to his profound knowledge of these rocks, inexhaustible patience, a ceaseless energy and a love of science which became his second nature. He was elected a Fellow of the Royal Society in 1934, and was the guiding spirit in the initiation of the National Institute of Sciences of India of which he was the first President in 1935.

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After working for a number of years on the Archæan rocks of the Nagpur, Bhandara and Chhindwara districts of Central Provinces, Fermor produced a detailed map of a complex of highly metamorphosed calcareous and argillaceous sediments with igneous intrusions which he grouped under the name of the Sausar series. The rocks consist of banded calcitic rocks, impure marbles, large bodies of manganese-ore of various types, quartzites, various types of schists and metamorphosed lava flows. They have been divided up into a number of stages which have a remarkable constancy over the area in which they have so far been mapped. In addition to the metamorphosed sedimentary rocks, there are a variety of porphyritic and fine grained granites, pegmatites and ortho-

gneisses which are younger than the Sausar series, and an injection gneiss which has gone by the general name of 'streaky gneiss'. A less metamorphosed group of Archaean sediments, perhaps an upward continuation of the Sausar series and designated as the Sakoli series, was considered by S. K. Chatterjee to have been formed as a result of retrograde metamorphism. W. D. West brought forward evidence to show the complexity of folding present in the rocks of the Sausar series, having mapped a *nappe* structure at Deolapar, near Nagpur, whereby different facies of the series, originally deposited far apart, had been brought into juxtaposition.

In Singhbhum, J. A. Dunn studied the Iron-ore series, named by H. C. Jones to include a suite of metamorphosed sediments and basic lavas, of which the banded hematite-quartzite is the most important member on account of its containing large deposits of high grade iron-ore, mostly hematite. In South Singhbhum the Iron-ore series is little metamorphosed or disturbed; but northwards both the metamorphism and folding increase, until in North Singhbhum the rocks are highly metamorphosed and severely folded. Although Jones had previously considered the Iron-ore series partly on account of its little metamorphism in South Singhbhum and partly on account of the fact that it rests unconformably on older metamorphic rocks, as likely to be of Cuddapah age and so younger than the underlying metamorphic rocks, Dunn included both of them under one system. The chief reason Dunn put forward for supposing them to be older than Cuddapah was that they are intruded by gneissic granites which are themselves intruded by dolerites, in place metamorphosed to epidiorites. And since no intrusions of dolerites have been known in Peninsular India between Cuddapah and Jurassic times, Dunn concluded that the Iron-ore series, the granites, the dolerites, and the folding and metamorphism were all older than Cuddapah, and therefore Archæan in age. The granite-gneiss and the various granites in Singhbhum have been studied in detail by Dunn, L. A. N. Iyer and A. K. Dey who worked together in that area for several years.

Other Surveys

In the Satpura range around Pachmari in Central Provinces, Crookshank mapped an area of Gondwana rocks and made critical observations regarding the passage of intrusive feeder sills into lava flows.

In South India, A. L. Coulson and P. N. Mukherjee studied the barytes and asbestos deposits in the Ceded districts of Madras, and Coulson published a couple of memoirs in this connection. In Assam, C. S. Fox commenced an investigation of the Tertiary coal deposits, laying special attention to the revision, on modern topo sheets, of La Touche's mapping of the Garo hills' coalfield. In 1933 A. M. N. Ghosh's services were placed at the disposal of C. A. Matley, leader of the Percy Sladen Trust expedition when an extensive tour of the Central Provinces was made along the outcrops of the Lameta beds of that State as a result of which a large collection was made, at Jubbulpore, of fossilised remains of the extinct order of reptile known as Dinosauria. Later Ghosh accompanied a punitive expedition to the unexplored areas of the Dibong valley in the Mishmi hills of the Assam Himalaya and reported a variety of schistose and gneissose rocks overlying Tertiary sandstones.

The Bihar and Baluchistan Earthquake

The Bihar-Nepal earthquake of the 15th January, 1934, which devastated large tracts of the Gangetic plain of Bihar and parts of the Katmandu basin in Nepal, was described by D. N. Wadia, J. A. Dunn, J. B. Auden and A. M. N. Ghosh. Damage to structures in the deep alluvial zone took place by slumping into the ground, whereas in the bordering regions closer to rock outcrops it was by shattering and collapse. The worst emissions of sand along vents and fissures took place in this slump belt, which had an area of 4,700 square miles. The postulated main line of failure took place in North Bihar below more than 6,000 feet of alluvium. Dunn considered it possible

that the narrow zones of higher isoseismals lying in lower isoseismals south of the main rupture were due to shearing along subsidiary fractures parallel to the main one. The authors prepared a seismic map of India and put forward recommendations regarding a building code.

W. D. West described the severe earthquakes of Mach on August 25th and 27th, 1931, and of Quetta on May 31, 1935, both in Baluchistan, and showed how the 15 shocks which had affected Baluchistan since 1852 were clustered mainly around the fold deflections of the Quetta re-entrant. Catastrophic though the Quetta shock was, with a loss of 25,000 lives, its instrumental magnitude was 7.3 as compared with 8.2 for the Bihar-Nepal shock, and its focus was shallow, being under 10 kilometres. It was shown that the major damage was incurred by buildings located on damp alluvium, whereas those on the drier alluvium to the north escaped the worst destruction. Using the results of the observations of the earlier workers, West prepared an isoseismal map of India broadly defining the various seismic belts of different intensities.

In Burma, Clegg continued the mapping of the Mogok Stone Tract that had been commenced in pre-retrenchment days by Coggin Brown and A. K. Banerji. Clegg was joined at a later date by L. A. N. Iyer. Bradshaw assumed charge of the duties of the Resident Geologist and Official Member, Yenangyaung and Singu Oilfield Advisory Boards at Yenangyaung. V. P. Sondhi continued his work in the Northern and M. R. Sahni in the Southern States.

At headquarters W. D. West studied the sequence of Deccan trap lavas disclosed by deep borings for water in Kathiawar (Saurashtra) and indicated that the various types of oceanite, ankaramite, limburgite and normal plateau basalt were extruded, without regard to order, from magmas which must have been available for tapping throughout the eruptive period. The primitive parent magma is considered already to have undergone differentiation before Cretaceous times into ultra-basic and normal types.

Publications

Of the few *Memoirs* that were published between 1931 and 1935, the more noteworthy were those by Fox on the Gondwana system and on the Lower Gondwana coalfields of India; Gee's Geology and coal resources of the Raniganj coalfield; Auden's Vindhyan sedimentation in the Son valley; and Jones's Iron-ore deposits of Bihar and Orissa. Of papers in the *Records* mention may be made of Coggin Brown and Sondhi's Geological account of a reconnaissance in the southern Shan States; Auden's Geology of the Krol Belt; Auden and Ghosh's Preliminary account of the Bihar-Nepal earthquake of January 15, 1934; Auden's Traverses in the Himalaya; and West's Account of the Baluchistan earthquake of May 31, 1935.

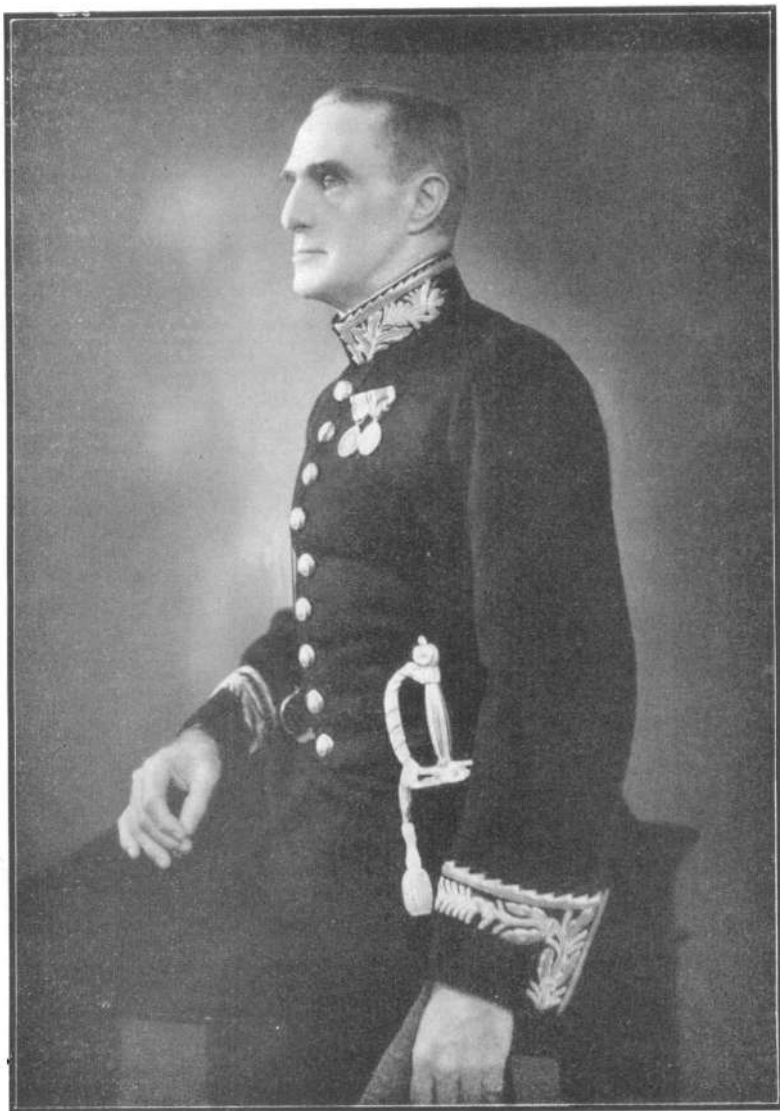
After a service of 33 years Fermor retired on the 7th November, 1935. The series of publications on the correlation of the Archæan formations in various parts of India, which he wrote before and after his retirement, testified to his profound knowledge of these rocks, inexhaustible patience, a ceaseless energy and a love of science which became his second nature. He was elected a Fellow of the Royal Society in 1934, and was the guiding spirit in the initiation of the National Institute of Sciences of India of which he was the first President in 1935.

A. M. HERON

1935--1939

Fermor was succeeded by A. M. Heron, who became Director on the 7th November, 1935. Heron had a reputation of being a tough but sound field-geologist and competent stratigrapher. He had spent the greater part of his career in the field, mostly in Rajputana, with a break of a couple of years in Burma where he worked with Coggin Brown in the tin and wolfram areas of Tavoy during the first World War. He had described the geology of Rajputana in three *Memoirs* and in several papers in the *Records*. Heron also wrote a valuable paper on the mineral resources of Rajputana in the *Transactions* of the Mining and Geological Institute of India, and with Coggin Brown described the geology and ore deposits of the Tavoy district. To Heron fell the lot of imparting field training to a number of junior officers, and his chief object was to see them turning out hardy and practical field-geologists. A thick-set, sturdy Scot, he was an able mountaineer, and accompanied the first Mount Everest expedition in 1921 and worked out the geology of the area around Mount Everest. Heron possessed strong common sense and a grim sense of humour, and was a strict disciplinarian in administrative matters. His grasp of the fundamentals, clear perception of the subject matter and balanced judgment fitted him ideally for the post of Director. His pithy remarks on the files showed his aversion to getting entangled in a maze of detail and argument.

Heron's Directorship was in a period of comparative quiet, and all the surveys initiated by his predecessor were continued. Due to the creation of an additional post for Burma, the retirement of L. L. Fermor and the resignation of C. T. Barber in 1935, P. K. Ghosh, M. R. Sahni and A. M. N. Ghosh were promoted to the senior grade, but Chibber resigned in the same year as Heron had assumed charge as Director.



A. M. HERON

On the 1st April, 1937 Burma separated from India, and the Burma Circle, then consisting of Clegg, Bradshaw and A. B. Dutt, became the Burma Geological Department, but for all practical purpose functioned as an appendage of the parent department till the retreat of the Allied Forces during the invasion of Burma by Japan in 1942. In the senior grade, Chibber's vacancy was filled by the recruitment of B. C. Roy in 1937, and three vacancies in the junior grade were filled by the appointments of V. R. R. Khedker, P. C. D. Hazra and A. B. Dutt. For a period of nearly five months from November 1936, M. S. Krishnan worked as a Member of the Coal Mining Committee.

The North-West Himalaya

After a spell at headquarters where he worked as Palaeontologist, Wadia resumed his survey of the Pir Panjal range in the Kashmir Himalaya in continuation of his previous work in Poonch, joining it up with Middlemiss's map of the Banihal pass. Wadia's work shows that the greater part of the summit zone of the range is composed either of Panjal trap or the Agglomeratic Slate series, with small outcrops of Gondwanas. Wadia also concluded that the greater part of the Panjal trap consisted of sub-aerial lava flows composed of basalt, and that the Agglomeratic Slate series is undeniably volcanic in origin.

As a result of work in the Potwar area, Wadia indicated the probable existence of an oilfield at Joya Mair, which was confirmed by subsequent drilling. Wadia proceeded on leave for six months in October, 1938 preparatory to retirement, after gaining an international reputation for his work in the North-West Himalaya, which earned him the much coveted Lyell medal of the Geological Society of London. The price he had to pay amounted to the loss of his first wife in an inhospitable terrain in the Himalaya. Wadia's text book on the Geology of India has been a reference book for generations of students. After retirement, Wadia became the Mineral Adviser to the Ceylon Government. He returned to India seven years later

as Mineral Adviser to the Government of India, and conceived the idea of and actually was responsible for the initiation of the India Bureau of Mines, of which he became the first Director, to be relieved later by M. S. Krishnan. Wadia is now the Honorary Mineral Adviser to the Department of Scientific Research, and controls the geological activities of the Atomic Energy Commission.

Field work in other parts of the Himalaya was resumed during Heron's period of Directorship. Mapping in great detail was carried out by Auden in Tehri Garhwal and Garhwal and by West around Shali. The result of their work has been to show that the Nummulitic and Dagshai rocks occur for considerable distances into the hills beyond Chakrata and Simla, resting variously on autochthonous Simla slates, para-autochthonous dolomites, and the overthrust units, and in all cases overlain with thrust contact by older rocks. It became evident therefore that the Nummulitic sea must have extended far to the north and that the areas in which the formation was deposited were geographically telescoped by the Miocene movements. A series of tectonic windows were in fact found to extend from Larji to Rampur, Shali, Deoban, Garhwal and Kumaon, which are shown in the structural map accompanying Auden's paper on new limestone and dolomite occurrences in northern India. Within the windows lie para-autochthonous dolomites, quartzites, slates, epidiorites and volcanics of Panjal type, surrounded and overlain by the schistose members of the Garhwal, Chail and Jutogh units, with their injections of gneissic granite. The roots of these overthrust units lie in the main ranges. West described an earlier recumbent folding and metamorphism in the Jutogh series long prior to the overthrust movements.

The intensely metamorphosed rocks of the southern main range in Tehri Garhwal and Garhwal, which were formerly classified by Griesbach as Vaikrita, were found to pass northwards, with decrease in granite and pegmatite intrusions, into unaltered Haimantas. Along the upper Nelang Gadh close to Tibet, these Haimantas are indistinguishable from the Simla

slates of the autochthonous foundation which occur in the southern Himalayan front. It is clear, therefore, that the Pre-Cambrian and early Palæozoic foundation of the Tethys and Cis-Tethys geosynclines had been broken up on one margin of the Himalayan tectogen into a series of tectonic units, both over-riding and carrying on the backs different elements of the younger sedimentary cover.

As a result of work carried out in 1933 and 1937 in the Karakoram and Aghil ranges, Auden found evidence for considerable metamorphism in the Palæozoic and Permo-Carboniferous rocks of the K², Sargo Laggo and Panmah areas, and considered that much of the metamorphism in this region was of Tertiary age. This is in agreement with the investigations of the German geologist P. Misch in the Nanga Parbat area. The surveys in this difficult mountain terrain have not yet established the existence of *nappes*. Minor recumbent folding has been found in the Biafo metamorphics, and a granite thrust was established in the Aghil range along which it is thought that a consolidated but still hot granite intrusion was brought up in solid form to its present position across the flank of a Mesozoic syncline.

The Himalaya have thus been found by the work done between 1925 and 1939 to possess considerable complexity of structure, with major thrust movements involving translation of 100 Km. and more.

In the North-West Frontier, A. L. Coulson carried out systematic mapping of the Mesozoic sediments and marine and fresh water Tertiaries of Baluchistan and Waziristan in continuation of Vredenburg's mapping in these regions.

The Peninsula Archæans

In Bastar, Central Provinces, H. Crookshank and P. K. Ghosh continued the mapping of the Archæans and the Cuddapahs in the neighbourhood of the Bailadila range, which had already been reported by P. N. Bose to contain large deposits of high grade iron-ore. Crookshank and Ghosh mapped the iron-ore deposits of the range and estimated the

reserves, the results of which have appeared in a paper in the Transactions of the Mining and Geological Institute of India. The Archæan rocks of Bastar consist of a complex of pelitic and psammitic sediments and lava flows, metamorphosed into various types of schists and quartzites. Granitic gneisses with associated pegmatites and hornblende-schists and injection gneisses also occur together with epidiorites. The most important formation is the banded hematite-quartzite containing large quantities of high grade iron-ore. Crookshank differentiated three Archæan groups, which could be correlated partly with the Archæan rocks of Singhbhum and partly with the Archæan crystalline schists of the C. P. In Bastar, P. K. Ghosh came across a suite of rocks resembling the charnockites of South India. Similar rocks have been noticed in Mysore by B. Rama Rao. Ghosh and Rao are inclined to regard the charnockites not as simple igneous intrusive rocks but as formed mainly from the recrystallisation of a complex series of sedimentary and igneous rocks of diverse origin and age.

Elsewhere mapping in Archæan terrain was carried out by D. Bhattacharji and B. C. Gupta in Central Provinces and by A. K. Dey in Jashpur, C. P. In Gangpur, Orissa, Krishnan distinguished a group of basal phyllites older than the Iron-ore series of the adjacent Singhbhum district, Bihar. The Gangpur series is characterised by manganiferous rocks, manganese-ore and calcitic and dolomitic marbles and limestones, and resembles lithologically similar rocks of the Sausar series of the C. P. Accordingly Krishnan has correlated the Gangpur series with the Sausar series. The Gangpur rocks are separated from the Singhbhum Iron-ore series by a belt of crushing, so that the relation between the two is obscure.

Assam and Burma

In Assam, Fox had nearly completed his surveys of the Garo hills by the end of 1938, and was able roughly to estimate the reserves of the coal deposits of Tertiary age of that area, and to throw light on the structure of the coalfields which he had

mapped. In the course of his work, he noticed that marine Cretaceous beds were not so extensive as had been supposed by Oldham, Medlicott, Hayden and La Touche. Accordingly, he set A. M. N. Ghosh to solve the problem of the Cretaceous-Eocene succession of the Khasi hills. Ghosh was able to detect a stratigraphical break between the Cretaceous and the Eocene on the Khasi hills plateau but did not notice any such feature in the southern foot-hills in the direction of the open sea. Ghosh was able to show that the maximum transgression of the sea in that region took place in early Eocene times and not during Upper Cretaceous as was previously supposed.

In Burma, Clegg and Iyer continued the survey of the Mogok Stone Tract. According to Iyer all the rocks of the Mogok area are of Archæan age as had been suggested by previous observers. On the other hand Clegg considered that some of the rocks, and especially the gem-bearing limestones of Mogok, might be of a later age and that it is quite possible that the limestones were metamorphosed by igneous intrusions during the preliminary uplift of the Shan plateau from the sea in post-Triassic times. In 1937 Sondhi accompanied the Sino-Burma Boundary Commission on the border of Yunan and north-eastern Burma, and found an extension, eastwards, of the rocks of the Northern Shan States. Sondhi and Iyer were transferred to India from Burma in April, 1937 when Burma was separated from India, but A. B. Dutt remained and continued mapping in central Burma.

Early in Heron's Directorship a beginning was made in the Survey in the study of polished sections of ore in reflected light by J. A. Dunn. The technique was made use of in the study of meteorites by J. A. Dunn and P. K. Ghosh, leading to the observations by Ghosh of certain chondritic structures in the crust of meteorites which were not recorded before.

After retirement, Heron joined the Geology and Mines Department of Hyderabad State (Deccan) as Special Officer, in which post he continued till 1949, when he joined the Pakistan Geological Survey.

C. S. FOX

1939—1943

C. S. Fox was appointed Director on March 25, 1939, when the Department consisted of the following :—

Superintending Geologists:

E. L. G. Clegg,	A. L. Coulson and
H. Crookshank,	J. A. Dunn.

Geologists:

E. J. Bradshaw,	P. K. Ghosh,
W. D. West,	M. R. Sahni,
E. R. Gee,	A. M. N. Ghosh,
M. S. Krishnan,	B. C. Roy,
J. B. Auden,	H. M. Lahiri and
V. P. Sondhi,	L. A. N. Iyer.

Assistant Geologists:

D. Bhattacharji,	V. R. Khedker,
B. C. Gupta,	P. C. Das Hazra,
P. N. Mukherjee,	A. B. Dutt,
A. K. Dey,	A. G. Jhingran and

G. C. Chatterji.

Chemist:

R. K. Dutta Roy.

Assistant Chemist:

Mahadeo Ram.

Curator:

P. C. Roy.

Field Collectors:

N. K. N. Aiyengar and M. S. Venkatram.

Museum Assistants:

D. Gupta, B. G. Deshpande and P. K. Chatterjee.



C. S. FOX

By 1937 the mineral rights of the Provinces had already passed under the control of the respective Provincial Governments, which commenced taking an active interest in mineral development. The Geological Survey attended to such mineral enquiries and problems of engineering geology and water supply as best as was possible with the small staff. But its main pre-occupation was still mapping, either the revision of the old maps, or continuing the maps into new areas, clearing up structural anomalies, and throwing light on the correlation of the stratigraphical units.

North-Eastern Circle

Immediately prior to taking charge as Director, Fox himself with his party in Assam, consisting of V. P. Sondhi, A. M. N. Ghosh, P. N. Mukherjee and V. R. R. Khedker, was continuing the mapping in the Khasi and Jaintia hills, and was pre-occupied in his search for clues for the Cuddapah age of the Shillong series and the Tertiary age of the Cherra sandstones.

North-Western Circle

Coulson continued his mapping of Kashmir and the Malakand district of N.W.F.P., correlating the Maneri limestone with Carboniferous limestone of the Khyber and the Tirah, while Gee was engaged in the Salt range, examining the junction of the Saline series and the overlying strata, and in Kashmir with the object of continuing the mapping of Wadia southwards from the Jammu-Banihal road towards Kistwar and Bhadarwah.

Gee also made a joint examination, with Messrs. A. N. Thomas and A. Alison of the Burmah Oil Co. Ltd., of certain sections of the Khojak shales in north-western Baluchistan which confirmed Vredenburg's conclusion that the shales belonged to the Oilocene age.

Auden in the Central Himalaya in Tehri Garhwal joined up his previous mapping in the region with that of Middlemiss

around Dudatoli, and continued his mapping right up to the Tibet frontier; this work led to the discovery that the Garhwal series, formerly called the Barahat series, occurs in a tectonic window. H. M. Lahiri with P. C. Das Hazra continued their work in the Kangra and Gurdaspur districts and Chambal, critically examining the structural features and stratigraphical positions of several units.

Southern Circle

J. A. Dunn with B. C. Roy, L. A. N. Iyer, D. Bhattacharji, B. C. Gupta and A. K. Dey were in the Southern Circle, where Dunn was engaged in separating his Kolhan series from the upper part of Jones's original Iron-ore series. Iyer commenced the mapping of the Kodarma mica belt on 4" to 1 mile maps, while the others continued their mapping of the crystallines into the hitherto unmapped areas in Orissa, Central Provinces and the Eastern States Agency.

Burma Geological Department

The officers who were on loan to the Burma Geological Department consisted of E. L. G. Clegg, Superintending Geologist with E. J. Bradshaw, Resident Geologist in the Yenangyaung Oilfield, A. B. Dutt, Assistant Geologist and R. L. Sharma, Assistant Chemist. They carried out mineral investigations on coal, gold, iron-ore, petroleum, wolfram, etc., and also attended to engineering geology and water supply questions. Clegg was considering the question of the likelihood of the Mergui, Moulmein and Mauchi series being equivalent and ranging in age between the Carboniferous and the Cretaceous.

World War II

Soon after his appointment as Director, World War II broke out. Fox who had seen active service in France during the First World War, at once geared into feverish activity

the resources of the Geological Survey for military aid. Almost immediately he prepared a series of memoranda between September, 1939 and June, 1940 dealing with the utilisation of the Geological Survey of India in time of war, and with the more important problems relating to minerals, particularly with regard to their development, processing and utilisation in India. In this way he prepared the ground on which the Department was rapidly to grow.

The Provinces were not so much interested in geological surveys as in the exploration, proving, opening and showing the workability of the mineral deposits. Such development work was, however, hampered by lack of equipment or qualified personnel. Industrialists were not prepared to sink capital in expensive plant for mineral utilisation except in the case of a few industries. It was, therefore, felt that there was an uncomfortable "no man's land" between the stage at which the Geological Survey report the possibilities and the stage of commercial development.

Fox's recommendation to create an Utilisation Branch of the Geological Survey to bridge the gap was approved in principle by the Government of India in April 1942, within 18 days of the submission of his memorandum, and a start was made by securing the technical personnel then available from Burma and Malaya.

The Utilisation Branch Operations

Zawar Mines, Udaipur:

The biggest of the operations under the Utilisation Branch was at the ancient lead-zinc mines of Zawar in Mewar State, where the ancients had worked the lodes to the ground water level. J. B. Auden, with Mining Engineer Mr. Hodgson, made a preliminary survey of the mineralised area of Zawar in 1941, as a result of which they selected the Mochia Magra area out of the four sites examined by them, and recommended that the first adit be started at Mochia Magra below the ground water level.

W. P. Cowen, General Manager, Mawchi Mines, who had been evacuated from Burma, was appointed Mining Engineer with the designation Officer on Special Duty, Utilisation Branch, Zawar Mines in 1941, the mining operations commencing in May, 1942. By 1943 he had the following on his staff : H. G. Smith and G. L. Brown Douglas (Mining Engineers), G. L. Symes (Mechanical Engineer), T. K. Chanda (Assistant Mining Engineer), Kusheswar Rai and N. L. Pasi (Probationer Mining Engineers), P. C. Roy (Metallurgical Chemist), M. A. Anandalwar and R. A. Nagarajiah (Surveyors).

The Utilisation Branch metallurgists, J. Fleming, H. H. Robottom and P. I. A. Narayanan, carried out work on the beneficiation of the Zawar ores, the Koh-i-Sultan sulphur and other minerals in the metallurgical laboratories of the Indian Copper Corporation.

On the temporary closing down of the Indian School of Mines, Dhanbad, the Professor of Geology, Dr. S. K. Roy, was deputed to carry out a detailed geological survey of the area. He was followed by H. Crookshank with G. N. Dutt, S. M. Mathur and A. Mukherjee, these three being recruited as post-graduate scholars under the Utilisation Branch; and the question of water supply required for the camp at Zawar was dealt with by Auden.

Cowen and his staff were able to drive five adits, and had just commenced recovering the ores when the war situation improved and communications were re-established with the south-eastern Asian countries and Australia. It was therefore considered no longer necessary to develop the mine, as lead and zinc would be available at a cheaper rate from overseas.

The operations were actually wound up by C. V. Thornton in April, 1945, and sold to a private company, the Eastern Smelting Co. Ltd., who are now working the mine.

Mica Production Section, Rajputana:

Crookshank, who was the only officer allowed by Fox to join the Army, became Garrison Engineer to his regiment in

the North-West Frontier. He was shot in both legs in an ambush and was flown back to Rawalpindi, and on his recovery appointed Officer-in-charge of the Mica Production Section, Rajputana, during 1943-44. He was assisted in Mining matters by R. D. Lawton, Mining Engineer, and B. Bhargava, Assistant Mining Engineer. At the same time an intensive search was made for beryl and rare earth minerals, in which work he was assisted by G. N. Dutt, S. M. Mathur and A. Mukherjee. Probably the first area in India to be surveyed aërially for geological mapping by the Survey was Zawar, on which maps Crookshank and his party mapped the area. The party had also an opportunity of visiting all the mica mines of Rajputana, and the data collected by them was embodied in a valuable paper entitled, "The Pegmatites of Rajputana".

Part of Crookshank's function was to recommend supplies of stores as well as mining machinery, petrol, etc., to the mica miners for augmenting production. These requirements were procured by the Stores Purchase Section of the Geological Survey under a Special Officer, Mr. E. C. Dixon.

Crookshank continued in the Mica Production Section until his recall to headquarters in 1944 on the sudden illness of the then Director, E. L. G. Clegg, when J. B. Auden took over charge of the Mica Production Section from him.

Mica Production Section, Bihar:

In the Bihar field, J. A. Dunn was appointed Officer-in-Charge of the Mica Production Section, the duties of the section being the same as those in Rajputana. The classification of the commercial grades of mica and their geological occurrence were recorded at this time by Dunn in his bulletin on "Mica", and by John Podger, Mica Inspector for the Joint Mica Mission, in a paper in the *Records*. Dunn's place was later taken by J. T. K. Crossfield as Field Officer, Mica Production Section, Bihar.

Mica Production Section, Madras:

K. C. Maithal and subsequently G. V. D. Upadhaya were field officers in the Mica Production Section, Madras, of which M. S. Krishnan was in charge in the beginning.

Government Mica Mines, Mahesri:

These mines were acquired by Government to ensure a steady supply of mica from the large group of mines in this area, the steady production of which might otherwise have been jeopardised by local politics. L. A. N. Iyer was appointed the first Agent, Government Mica Mines, Mahesri in December, 1942, holding the post for six weeks or so. He was followed in this post by A. M. N. Ghosh, who continued until the closing down of the operations in 1944.

Part of the work of the Agent lay in geologically surveying the area and in opening up the deposits in a scientific way, and in this work he was assisted by W. Douch, M. V. Subramaniam, N. L. Pasi, Enayat Karim, A. K. Roy, A. B. Moitra, N. Prasad, P. K. Ghosh, G. N. Dutt, Abdul Hai Khan, S. Guha, Ali Tayab, and Wajid Ahmed, in mining, surveying and geological work as necessary. Dr. B. B. Dutt was the Medical Officer to the staff.

The procurement of mica had reached such importance that the joint Mica Mission was set up by the U. K. and U. S. Governments in Calcutta. The Mission was housed in the Geological Survey of India with which it worked in close co-operation. Mica had to be got at any cost, and for this purpose supplies of suitable machinery had to be procured, no matter how.

Sulphur Operations, Koh-i-Sultan:

The presence of sulphur deposits in Baluchistan, in the extinct volcano of Koh-i-Sultan and at Sanni, was already known from the work of Vredenburg and Tipper. Gee made a preliminary investigation of the deposits in 1939-40, and with the chances of the overseas supplies being cut off, the development of the Koh-i-Sultan deposit was taken in hand,

that of Sanni being regarded as unprofitable to work. The operations which were commenced with E. R. Gee in charge were taken over shortly afterwards by the Supply Department and then passed on to the Baluchistan administration, under whose authority Gee took charge again as Officer-in-charge for the development of the deposits under the Utilisation Branch. On Gee being taken seriously ill, E. L. G. Clegg, who had returned from Burma by then, was sent to take charge of the operations, with C. V. Thornton as Mining Engineer, until Gee's recovery. Gee had the following staff : K. C. G. Heath (Senior Mining Engineer), T. C. Seth (Junior Mining Engineer), Mr. Tayab (Assistant Mining Engineer), with P. C. Das Hazra, Md. Tayab Ali, M. I. Ahmed and Abdul Hai Khan as geologists, and Mehr Alam, Mehdi Hussian, A. Wahid, Rashbehari Ghosh, and D. N. Sett as chemists. L. M. Pathuk was Surveyor, and N. H. Farshori Assistant Surveyor.

The operation continued till May 15, 1945, although on a reduced scale after the middle of 1944 when cheap imported sulphur became available.

Wolfram Operations :

The known occurrences of wolfram in the Bankura district, Bengal and in the C. P. were investigated in detail by M. K. Roy Chowdhury and D. N. Sett in the Bankura district, and by E. L. G. Clegg, A. G. Jhingran and R. K. Taploo in the Nagpur district.

Special Operations

Strategic Branch:

On the evacuation of Burma, E. J. Bradshaw arrived in India in 1942 when he was placed in charge of the Assam Party. He advised the military authorities and the Public Works Department regarding the suitability of sites for aerodromes, water supply, etc., and they found the advice tendered so useful that under the Defence Department

Bradshaw organised the Strategic Branch which was also housed in the Geological Survey of India.

Bradshaw had on his staff 8 G. S. officers, two Majors—G. S. 2, five Captains—G. S. 3, and one Squadron leader, who had returned from Burma and who were formerly attached to the Burmah Oil Company, together with one W. A. C. (I), Mrs. M. B. Baker. The Strategic Branch reported on questions of water supply, geology, road alignments, etc., for practically the greater part of South-Eastern Asia, reports which were highly appreciated by the military authorities.

Coal and Salt surveys in Afghanistan:

The Government of India sent W. D. West to survey and geologically explore for coal in northern Afghanistan during the three summers of 1940-42. West was accompanied in the first year by a Drilling Engineer, N. Mariano and a Mining Engineer, Mohd. Tyab, and in the second year by Mining Engineers, Messrs. Enayat Karim and Kazmi, with F. Ahmad. He was also assisted by a detachment of Surveyors from the Survey of India. His work lay not only in proving the coal deposits, but also in actually opening up coal mines. By 1942 he accomplished his task and was able to hand over to the Afghan Government a working proposition. In appreciation of his work that Government conferred upon him their decoration the "Star of Afghanistan".

E. R. Gee, together with Mining Engineer T. C. Seth, surveyed the salt deposits of Afghanistan in 1940 and wrote a comprehensive report suggesting methods for opening up and working these deposits.

Geological Survey of the Bihar Mica Belt:

Help was sought from and generously provided by the Surveyor General of India for a preliminary geophysical prospecting of the mica belt in Kodarma and Mahesri to ascertain if it was possible to determine the behaviour of the mica-bearing pegmatites in depth; and Gulatee under the general supervision of Col. Glennie, and Sharpley of the Indian

School of Mines carried out the investigation for a year, with L. A. N. Iyer to provide the geological background. Although it was not possible to come to any definite conclusion on the matter, due to ground-water effects, this should be regarded as the first attempt of the Geological Survey of India to apply geophysical methods of prospecting to minerals and ores.

Mineral Springs.

The investigation of the mineral springs of Bihar and of some of the important ones of Bombay, the U. P., the C. P., the Punjab and Bengal by P. K. Ghosh, B. C. Gupta and P. K. Chatterjee indicated their commercial possibilities. These waters were also bottled by the party and were found to be as good as some of the well-known foreign types, being appreciated by the then Viceroy of India.

Other Works

As stated earlier, the Provincial Governments as well as some of the States, to whom now belong the mineral rights, were anxious to have their States thoroughly surveyed and the minerals brought into productivity.

The Madras Government offered to pay for four additional officers for five years' work in the Madras Presidency, the following officers being selected for the purpose : R. N. P. Arogyaswami, T. N. Muthuswami (followed by S. S. Gauher), S. Narayanaswami, and V. Subramanyam. They were later absorbed in the cadre of the Geological Survey.

For the Eastern States Agency, similarly, one Geologist and three Assistant Geologists were appointed, B. C. Gupta being the Geologist, H. Nandi, K. K. Dutta and Mukti Nath being appointed as Assistant Geologists.

Apart from the work in the Utilisation Branch, the work of the Geological Survey officers was confined more or less to economic investigations, and engineering and water supply problems, geological mapping being continued on a modest scale.

Gee was able to investigate the Quetta earthquake of the 29th September, 1941. H. M. Lahiri advised on the sal-ammoniac industry in the Punjab and soil erosion in the catchment of the Beas river; while M. R. Sahni and B. G. Deshpande investigated water supply questions in Karachi city and other parts of Sind, and the lignite deposit of Meting. Auden investigated the reh soils with B. C. Gupta and P. C. Roy, and examined the weir-sites on the Dhanan river with P. C. Das Hazra. Fox initiated a study of the salinity conditions of the Hooghly river and of the wells in the neighbourhood, between high and low tides, in which P. K. Ghosh and D. N. Sett were engaged for sometime, the work being facilitated by the courtesy of the Port Commissioners of Calcutta.

W. D. West carried out an estimation of reserves of manganese-ore in the C. P., and B. C. Gupta estimated the reserves of vanadium-ore in Mayurbhanj State.

Coal was investigated in the Santal Pargannas by G. C. Chatterji, and in Korea State by K. K. Dutta; bauxite in several parts of Bihar and the Central Provinces and the Eastern States by M. K. Roy Chowdhury, Mukti Nath and P. K. Chatterjee; gold in Wynaad by H. Crookshank; graphite in Koraput and in the Sambalpur district by A. M. N. Ghosh and B. C. Roy respectively; pyrite deposits in the Shahabad district and in the Simla hills by Auden; nickel and cobalt ores in Nepal by A. G. Jhingran; the mapping of the Bihar mica belt by L. A. N. Iyer and of the Nellore mica belt by B. C. Roy; the iron-ore and magnesite deposit in Salem by N. K. N. Aiyengar; the lignite of South Arcot and the Bedadanol coalfield by M. S. Krishnan and R. N. P. Arogyaswamy; the phosphates and gypsum deposits of Trichinopoly by M. S. Krishnan; high grade limestones for carbide by A. B. Dutt and S. C. Chakravarty; limestone in Sankaridrug by N. K. N. Aiyengar; and bauxite in the Shevaroy hills by M. S. Krishnan.

Water supply and engineering problems were attended to by E. R. Gee and J. B. Auden in the Punjab and in the U. P. including the dam-site of Bhakra (Gee and Lahiri),

the irrigation projects of Delhi Province and Ajmer-Merwara by J. B. Auden, Bharatpur State by C. S. Fox, weir-sites of the Dhasan river by P. C. Das Hazra, the Tungabhadra dam-site by M. S. Krishnan and C. Mahadevan of the Hyderabad Geological Survey, the dam-site at Duduma water falls in Koraput by A. K. Dey, and water supply questions in the Central Provinces by A. M. N. Ghosh and D. Bhattacharjee.

Mapping, although on a much reduced scale, was continued in Assam in the Khasi and Jaintia hills, North Cachar and the Mikir hills by Coulson (until his retirement), V. P. Sondhi (until he was recalled to headquarters to hold the charge of the Officer-in-charge and Palæontologist), P. N. Mukherjee and V. R. R. Khedker. K. Jacob made some plant fossil collections from several Tertiary localities in Assam.

Mapping was also continued in the Salem and Trichinopoly districts in South India by Krishnan, Arogyaswamy, Jacob, S. Narayanaswamy, V. Subramaniam and T. N. Muthuswamy, and in the Koraput district by A. K. Dey and Mukti Nath. J. B. Auden assisted by S. P. Nautiyal and D. R. S. Mehta visited the old copper mines in Garhwal, and J. B. Auden visited several localities in the Darjeeling district.

The urge for the supply of minerals was so great that even the most distant parts of India were searched with the hope of procuring supplies. The antimony mine of Chitral was examined by V. P. Sondhi and Mukti Nath, and orpiment mines on the Afghanistan-Russian border in Chitral by V. P. Sondhi. Sondhi also advised on the construction of the Assam-Burma road.

Palæontology and the academic aspects of the Department's works were practically suspended.

During this period the system of associating post-graduate students with the officers of the Geological Survey was introduced, and after 1941 the following were admitted for training in field work, and all of them were later absorbed in the Department: F. Ahmad, A. Hai Khan, K. Jacob, M. K.

Roy Chowdhury, D. N. Sett, S. C. Chakravorty, D. K. Chandra, B. F. Mehta, Sanjana, P. K. Ghosh, G. N. Dutt, S. N. Sen, N. M. Khan, Mohsenul Haque, H. Nandi, G. R. Gibson, A. P. Subramaniam, R. Thiagarajan, A. P. Jain, S. M. Mathur and Anil Mukherjee.

Headquarters

There were several organisational changes at headquarters. The post of Assistant Director was abolished, and that of Officer-in-charge-cum-Palæontologist introduced, of which V. P. Sondhi was the first incumbent. The post of Personal Secretary to the Director was created in 1940, and filled by Manomohan Ghose, at present Registrar of the Department. The Petrologists in succession were P. K. Ghosh, J. B. Auden and L. A. N. Iyer. In addition to their normal duties at headquarters, and lecturing at the Presidency College, they had to investigate for short periods pressing problems of water supply, aerodrome sites, etc.

A. R. P.

In addition to evacuating valuable properties of the Geological Survey out of Calcutta, strong A. R. P. measures were adopted under P. K. Ghosh to ensure the safety of the existing personnel and office property. Fox frequently experimented with smoke screens, the efficacy of which was appreciated by the Military authorities and its nuisance value equally resented by the residents in the neighbourhood. The few officers at headquarters were heavily over-worked, and one of them is known to have lost all memory of his car which he had left parked on one of the busiest highways of Calcutta until the receipt of a threatening notice from the Police three day later.

Publications

Due to security reasons and to the shortage of paper, the publications of the Department suffered most. Fox introduced

the Economic Bulletin series of publications and Professional papers in the *Records* of the Geological Survey, the former being intended to replace the Quinquennial Review of the Mineral Production of India. Such of the *Records* and *Memoirs* as were published were mostly marked "Confidential and for official use only", and were unavailable to the public till well after the end of the War.

Provincial Headquarters

With the evacuation of the library and other valuable articles of the Department in 1942, the officers were also dispersed out of Calcutta, each Province receiving a nucleus of officers. These local centres were later to develop into the Circle offices which are now established in different Provinces.

When Fox retired in June, 1943, the Utilisation Branch was already in full operation with its annual grant raised to Rs. 56 lakhs against Rs. 5 lakhs of the Geological Survey proper, and he had succeeded in establishing a strong case for an expanded Geological Survey. It was indeed his hope that the Utilisation Branch would in course of time be merged with the Geological Survey of India as a permanent feature, and the operations under it provide specialist training in metal mining and metallurgical chemistry to young Indians. In his proposals to the Government of India on the Utilisation Branch one also finds that he had foreseen the necessity of starting a special section for engineering geology and ground water, the enquiries in which subjects had assumed very large proportions and had become of far too specialised a nature to be attended to by the normal staff of the Survey.

Fox retired on July 1, 1943, having left his mark on the Department in no uncertain manner.

E. L. G. CLEGG

1943-1944

E. L. G. Clegg was appointed Director on the retirement of C. S. Fox on July 1, 1943. He re-organised the headquarters organisation by introducing a post of Deputy Director which was filled by W. D. West, in addition to that of Officer-in-charge *cum* Palæontologist filled by P. K. Ghosh. The field circles were re-established with H. Crookshank in charge of the Western Circle, J. A. Dunn in charge of the Eastern Circle, E. R. Gee in charge of the Northern Circle and M. S. Krishnan in charge of the Southern Circle (the only Geologist in charge of a Circle), while the Strategic Branch continued to operate with Bradshaw in charge.

The work of the Department still continued to be chiefly connected with water supply and economic enquiries throughout India. The Utilisation Branch operations at Zawar and Koh-i-Sultan, as stated already, were no longer regarded as of vital importance to the prosecution of the war, as supplies had started to become available from overseas. The activities in the mica fields were, however, continued vigorously.

Gypsum Enquiry

At this time the Government of India set up a Technical Mission to advise them on the establishment of a large Fertiliser industry in India, one of the chief raw materials of which is gypsum, nearly half a million tons of which would be required per year. The investigations of P. K. Ghosh, K. K. Dutta and R. K. Taploo in Bikaner and Jodhpur States, and of P. C. Das Hazra, F. Ahmad and N. M. Khan in the Salt range showed the existence of gypsum in sufficient quantities to ensure a steady supply for many years, and on the basis of their reports the Sindri Fertiliser Project came into existence.



E. L. G. CLEGG

In Clegg's time the training camp of the Geological Survey was introduced for the training in geological field work of the new junior officers of the Department. The scope of this scheme has since been somewhat enlarged so as to include a limited number of post-graduate students from different universities of India for training in field duties.

Clegg died untimely at the age of 50 on the 8th September 1944. He was a man of great administrative ability and had a practical brain and excellent judgment.

H. CROOKSHANK

Officiating Director

1944-45

Almost a month before Clegg's death, H. Crookshank was asked telegraphically, when he was on the point of going on leave out of India, to take officiating charge of the post of Director, as Clegg had been suddenly taken ill. He continued to officiate in the post on Clegg's death until he was able to avail himself of leave.

By this time the call on the Geological Survey for mineral investigations and engineering geology and ground-water problems had assumed such important proportions that the Mineral Development and Engineering Geology Circle was initiated as a special section. The field circles continued as before, and special investigations on bauxite in the Ranchi, Balaghat and Sambalpur districts were undertaken, and the gypsum investigation in the Salt range continued. Important dam-site investigations were undertaken by J. B. Auden.

H. Crookshank joined the party of geologists consisting of E. S. Pinfold, J. Coates, E. H. Lehner, P. K. Ghosh, led by E. R. Gee, to collect geological evidence regarding the stratigraphical position of the Saline series of the Salt range. The party came to the conclusion that the position of the Saline series in the Salt range below the purple shales and sandstones was a normal undisturbed one.

Crookshank, before he went on leave, submitted a scheme for the expansion and reorganisation of the Department in which he recommended that by 1954 the total number of Geological officers be increased to 99, with 1 Geophysicist, 1 Mining Engineer, 1 Assistant Mining Engineer, 1 Chief Chemist and 8 Chemists against what existed then, *viz.*, 63 Geological officers, 1 Chemist, 5 Assistant Chemists, 5 Chemical Assistants and 1 Curator. The office staff was to be correspondingly increased from 70 to 75 with the inclusion of 1 Registrar

and 1 Additional Superintendent, and a budget grant of Rs. 16,00,000 as against Rs. 7,96,000 in 1944.

In submitting his proposals, Crookshank remarked that 'the proposed rate of recruitment should not be increased unduly because of our inability, with the few experienced officers now available, to give such adequate supervision as will ensure reliability of work.' He also urged upon the Government to make permanent all the temporary officers who were then serving in the Department in order to furnish the nucleus around which the expansion could take place.

Origin of the Recreation Club

The Joint Mica Mission staff as stated already were also housed in the Geological Survey building. It should be mentioned to the Mission's credit that they encouraged their staff to take part in recreations and sports. This had a healthy reaction on the staff of the Geological Survey, and H. Crookshank initiated the Recreation Club of the Geological Survey of India, which has now acquired a prominent place in Calcutta in the field of sports and dramatic performances.

J. A. DUNN

Officiating Director

1945

H. Crookshank availed himself of his long-deferred leave on the 27th February, 1945, when J. A. Dunn took over charge as officiating Director.

The Utilisation Branch operations at Koh-i-Sultan and Zawar closed their operations in 1945 and the Mica Production Sections also started closing down gradually.

A new section of Geophysics was started with G. Dessau, Geophysicist, assisted by A. Del Carlo. The engineering geology questions assumed very great importance and several important dam-sites, including multi-purpose high dams, were investigated in the Damodar valley, the Tista and Rangit valleys, Hirakud and Bhakra, and special investigations connected with industries were taken up, the chief of which were refractory clays and gypsum. Also the mapping of the Bokaro and south-eastern Jharia coalfields on large-scale maps was undertaken, and a detailed investigation of the lignite deposits of S. Arcot begun. Stress was now laid on systematic mapping, which was re-commenced in different provinces.

Dunn went on leave preparatory to retirement on 3rd December, 1945, with the satisfaction of knowing that Government had accepted in principle the expansion of the Geological Survey of India for which he submitted important and practicable plans. He had also got going the Mineral Development, Geophysical, Engineering Geology and Ground Water Sections, which were to gain much impetus during the next five years.



W. D. WEST

W. D. WEST

1945—1951

W. D. West took up his duties as permanent Director on the 29th December, 1945. The Government of India had by then already announced their intention to expand the Geological Survey of India permanently, and it fell to him to organise the Department for the long range peace-time requirements, as Fox had done for sustaining the war-effort. The schemes of expansion submitted by Crookshank and Dunn were before him, and he had also been closely associated with Fox in the latter part of his regime. His experience of organisational work arising out of his intimate knowledge of and association with the leading scientific and educational institutions in India were now of value to him and to the Department, and his Five Year Plan for the Expansion and Re-organisation of the Geological Survey was submitted to Government in July, 1946.

Re-organisation and Expansion

In re-organising the Department he supported Dunn's previous scheme for the formation of separate sections for Mineral Development and Engineering Geology and Ground Water, with the former of which were to be associated Geophysical, Exploratory Mining and Drilling Sections. He clearly emphasised that mapping should continue to be the basis of all sound geological work, and that reconnaissance for economic minerals without such a scientific back-ground would lead to disappointment. In this he voiced the opinion of the early founders of the Survey, John McClelland and Thomas Oldham, and a considerable portion of the work of the Department is now devoted to systematic mapping.

The Department had suffered from its publications having been left in abeyance during the war, and veiled and open criticisms were heard of the work of the Geological Survey

'behind the iron-curtain'. With the assistance of P. K. Ghosh he set about to remedy this defect, and reinstated the pre-war set up of the *Records* which had consisted of four parts including the General Report and the Annual Review of Mineral Production. The *Quinquennial Review of Mineral Production*, last published for the years 1929-33, was to be restored, and in the meanwhile the data for the period 1934-1946 have been collected and are already in the press.

He also introduced a new series of *Bulletins*: Series A—Economic Minerals, and Series B—Engineering Geology and Ground-Water, the first few numbers of which have either already been published or are in the press.

In addition, the semi-popular quarterly journal "*Indian Minerals*", contemplated by Dunn, was introduced, three volumes consisting of four numbers each having already been published, at the start under the editorship of Dr. D. N. Wadia after his retirement from the Department.

The first volume of the third edition of the Manual of the Geology of India, by E. H. Pascoe, which stands as a monument to the scholarship and industry of the author, and in the preparation of which West, assisted by Ghosh, had taken considerable pains, was published at last in 1950, 11 years after the receipt of the manuscript. The types weighing $2\frac{1}{2}$ tons which had already been set up, were melted down for munitions purposes during the early part of the war, and the printing had to be re-commenced in 1945. The 96 miles to one inch Geological Map of India, which appears in this volume, was specially prepared for the Manual, incorporating the latest available data.

The Statistical and Information Sections were enlarged and organised for a properly designed information service, and the Library and the Museum Galleries, which had suffered much due to the evacuation of the books and specimens as a safety measure during the war, were rehabilitated.

West re-organised the scientific work of the Department on the basis of five Mapping Circles, one Mineral Development Division and one Engineering Geology and Ground

Water Division, on a somewhat different basis from that suggested by Dunn. That part of the former Mineral Development Circle's work which was closely related to the work of the Mapping Circles became the responsibility of the Circles concerned, the work of the Mineral Development Division being confined to drilling, prospecting, exploratory mining and geophysical prospecting. Similarly with regard to the Engineering Geology and Ground Water Division, its specialist officers confined their attention to major projects or to particularly difficult problems. In this way each province was able to utilise the services of a central pool of specialists, the trained personnel of which were deputed to work in any place where the mineral potentialities awaited final testing.

The co-ordination of work at headquarters was carried out through two Deputy Directors, one for administration (P. K. Ghosh) and the other for technical duties (V. P. Sondhi), the latter being in charge of the Mineral Development Division also. A new section on Palæobotany under K. Jacob was initiated.

The Chemical Section (under R. K. Datta Roy), which before the war consisted only of one Chemist and one Assistant Chemist, was augmented, the sanctioned strength becoming one Chemist and 9 Assistant Chemists. The Section had had considerable experience of analytical work on rocks, ores and water during the U. B. operations (many of the officers being absorbed in the Geological Survey of India after closing down of the U. B.), and it is now able to deal with special problems including the testing of many industrial minerals.

The main difficulty that West had to face was the shortage of senior officers. Crookshank, who, on his return from leave, filled the post of States Liaison Officer, in which capacity he advised various States in Rajputana, the E. S. A., and Central India with regard to geological work and mineral exploration, retired in 1946 on reaching the age of 55. Dunn retired prematurely; Gee and Bradshaw retired from the Geological Survey of India for service in Pakistan and Burma respectively; while M. S. Krishnan was deputed to take charge

of the India Bureau of Mines as Director. These gaps were difficult to fill even in normal times, far less when the Department had grown to nearly four times its normal size with several new functions allotted to it, and while the new Sections were still in the stage of formation. There were also several retirements in the cadre of Geologist—L. A. N. Iyer, H. M. Lahiri, B. C. Gupta, P. N. Mukherjee, who had rendered valuable service and most of whom were still in good health, while Mahadeo Ram, Assistant Chemist in the Department for many years, died. Of the team of officers with whom Fox had begun his period of Directorship, thirteen senior had gone and West had only 17 left. With them, and with the more recent staff recruited since the war, he had to build up a nucleus with which to man the different sections. As senior men with sufficient experience could not be found to fill the senior posts, except in the Geophysics and Mining Sections, the recruitment had to be mostly to the junior ranks. For geophysics F. Ermisch and M. B. Ramachandra Rao were appointed as Geophysicists, for mining D. Kerr-Cross was appointed Mining Engineer, while V. H. Boileau was appointed Petroleum Geologist.

Serious efforts were therefore made to train the junior officers by means of the Training Camp already brought into being by Clegg in 1944; by improvement of the geological education in the Indian Universities, for which a Committee was set up consisting of D. N. Wadia, P. Parija and West, the latter having visited the Universities for the purpose; and by facilitating the deputation of the junior officers to Universities and other technical institutions overseas. Dunn had already arranged for the training of a batch of officers in an Australian University. More recently students who had acquired education and experience in the British and American Universities under the overseas scholarship scheme of the Ministry of Education, became available for recruitment. In the past the recruitment had proceeded at the rate of one or two per year, and each recruit worked under the closest supervision of an experienced officer. It was no longer possible to work on

this system, and great care had to be exercised in the selection and training of the officers by the methods stated above.

The Partition of India

During this period the partition of India took place. And though as a result a large tract of country no longer came under the purview of the Geological Survey of India, the latter became responsible for geological work in the former semi-independent Indian States which became part of the Union of India.

Mapping

In the surveys taken up, attention was mainly confined to those surveys which were concerned primarily with the elucidation of the general geology of the country, though more detailed surveys were made in areas known to be mineralised or containing rich deposits of minerals.

M. R. Sahni assisted by A. F. M. Mohsenul Haque and N. M. Khan mapped the area in the neighbourhood of Meting and Jhimirpur (Sind) containing lignite. The Wardha valley coalfield was surveyed by V. R. R. Khedker, and the Bokaro and Katrasgarh coalfields by A. B. Dutt and P. K. Ghosh respectively. The mapping in the Ranchi and Palamau district, rich in bauxite, was continued by M. K. Roy Chowdhury and Mukti Nath, the Koraput district by S. C. Chakravarty and Y. G. K. Murty, the Chanda and Yeotmal districts by B. N. Sinha, while the chromite belt of Singhbhum, first reported on by B. C. Gupta, was mapped in detail by G. H. S. V. Prasada Rao. An area in Himachal Pradesh (Mandi State) was also mapped, as also certain parts of Ajmer-Merwara (Rajputana), the Bhandara, Balaghat and Nagpur districts and Raigarh State in Madhya Pradesh, Vindhya Pradesh, and the blank areas in the Koraput, Ganjam, and Dhenkanal districts in Orissa. Mapping was also undertaken in Mudhol State, Bijapur and Politana by B. C. Roy, B. G. Deshpande and B. F. Mehta, and in Kutch by M. C. Poddar.

The mapping of the Himalaya was again taken up, G. N.

Dutt continuing the survey of Jammu State. V. H. Boileau, G. Kohli and B. N. Raina mapped the Jwalamukhi area in the Kangra district in connection with petroleum, while an area in Himachal Pradesh (Mandi State) was mapped by V. H. Boileau and G. Kohli in connection with the salt deposits.

A Danish expedition undertaken to the Spiti Himalaya in 1950, to which were attached A. G. Jhingran, G. Kohli and B. N. Shukla, showed that the structure is more complex than was supposed by Hayden and others, and indications were found that the whole Spiti zone with its superficial simple folds may have been thrust across the roots of the Garhwal *nappes*.

In southern Sikkim and in the Darjeeling Himalaya A. M. N. Ghosh found evidence of the overturning of the metamorphic zones whereby a succession of high grade metamorphic rocks now rest on less metamorphic rocks without visible signs of disturbance, and in the Rangit valley near Naya Bazar he found evidence for a closed window of Gondwana rocks below the Dalings, while surveys carried out by the Kosi dam-site party have established the existence of a semi-window of Gondwana rocks underlying the Dalings in eastern Nepal.

The South Indian districts of Anantapur, North Arcot, Salem, the Ceded districts, Nellore and Gudur, Sandur State, Ramnad and Tinnevely, East and West Godavari and Trichinopoly districts were mapped by B. C. Roy, S. Krishnaswamy, B. Srikantan, N. K. N. Aiyengar, S. Narayanaswamy, A. P. Subramaniam, A. K. Roy, V. Venkatesh, S. N. Sen, M. S. Venkatram, A. S. Ramiengar, M. Krishnamurthy, Mohd. Ziauddin, A. P. Subramaniam, R. Thiagarajan, N. A. Chandrasekariah, C. Ramaswamy, V. Gopal, T. Madhusudan Rao and others under the direction of M. S. Krishnan, and later on under A. G. Jhingran and A. K. Dey. In the north-eastern corner of India, mapping was continued into the Naogong, Naga hills and Sibsagar districts, Assam by D. K. Chandra and T. Banerjee.

Altogether the mapping of 30,000 square miles on the one-inch scale was completed.

Mineral Investigations

During this period the Department worked in close collaboration with several Government departments and with the industries, supplying them with information and data on raw materials. Sufficient limestone suitable for the manufacture of cement required for large dams was located and estimated, *viz.*, at Lanjiberna for the Hirakud dam by A. M. N. Ghosh with M. V. Rao and Mukti Nath and near the Nepal-Bihar boundary, for the Kosi dam. Sufficient quantities of limestone suitable for future cement industries were also located at Robertsganj, in the Mirzapur district, in Tinnevely, in Himachal Pradesh, in the Mikir hills, at Malla in the Ambala district and at other places. Chemical grade limestone was also located in Sirmur State and in the Mirzapur district, U. P. and in parts of Madras. Large deposits of magnesite, first brought to the notice of the Department by Mr. Robson of the Indian Copper Corporation, were examined in detail in the Kumaon hills. The work in the Bihar mica-belt was also continued.

Explorations of some of the old copper mines in the Sikkim and Darjeeling districts and in Rajputana and also the Zawar lead-zinc mines in Rajputana were undertaken by D. Kerr-Cross and his party of the Mining Section, his reports on Zawar and the copper deposits of Rajputana being re-assuring.

In the course of systematic field mapping, several deposits of manganese-ore came to light in the Kalahandi district, which are being further explored, while a preliminary investigation along with mapping was undertaken in the Bonai area, in Orissa for the location and estimation of the reserves of manganese-ore. The investigation of the iron-ores of Bopai under the general supervision of the Geological Survey was taken up by Mr. M. V. Rao of the C. W. I. N. C., and a search is being made for flux and furnace grade limestones and

dolomites, fire-clay and other refractories for the proposed steel works in Orissa. Similarly, the large iron-ore deposits of Raoghat have been investigated by D. K. Chatterjee for the proposed steel works in Madhya Pradesh.

Special Mineral Investigations

With the separation of Pakistan the gypsum-anhydrite deposits of the Salt range were lost to India. Prospecting for these minerals was therefore carried out in Kutch, Saurashtra and several parts of Rajasthan by D. R. S. Mehta and G. G. K. Sastri with considerable success.

The Government of India invited three consulting firms to advise on the question of setting up new iron and steel industries in India, and memoranda on the raw materials including iron-ore, manganese-ore, refractory materials, coal, etc. were prepared by the Department and furnished the basis for the report of the consultants.

A special party consisting of A. B. Dutt (in charge), P. K. Ghosh, G. N. Dutt, K. D. Shukla, K. S. Mahapatra, K. Balu, N. Venkatappayya, C. A. Narasimha Rao, R. B. Ghosh and N. Mariano investigated four coal producing areas : East Raniganj, East and West Bokaro, Ramgarh and North and South Karanpura, proving the existence, in all the four areas, of sufficient suitable coal at shallow depth for synthetic petroleum plants, the supply being sufficient for 30 years or more in each case. In the opinion of Dutt, the establishment of a synthetic oil-plant is an immediately practicable proposition in the Ondal area and of the East Raniganj coalfield so far as geological considerations are concerned.

A survey of fire-clays and of the raw materials required for the ceramic and glass industries was undertaken in the various Provinces in 1945 and continued to the present time. This work was carried out by B. C. Gupta, R. N. P. Arogyaswamy, D. R. S. Mehta, A. P. Subramaniam, K. D. Shukla, R. Thiagarajan, G. G. K. Sastri, S. N. Puri, P. C. Sogani,

K. K. Chopra and D. P. Bahl. They worked at different times and in different places, and submitted a number of detailed reports.

Geophysical Prospecting

The Geophysical Section became poorer through the loss of G. Dessau, who had started and organised the Section, and later, of F. Ermisch and of the brilliant technician A. Del Carlo, the work at present being in charge of M. B. Ramachandra Rao. During the short period of its existence, the work of the section, with limited resources at its disposal, has indicated the hidden boundary of the Kamptee coalfield so that it will now be possible to undertake the siting of boreholes for coal in the area; the depths of bedrock in the case of several proposed dam-sites; the presence of pockets of manganese-ore in depth in the C. P.; the possibility of the continuation of graphite deposits in depth in Athmallik; and also the probable depth of ground-water level in certain tracts of Rajputana, etc.

Damodar Valley Survey

In connection with the multi-purpose Damodar Valley Project, Geologists were lent to that operation to carry out the detailed geological mapping and mineral prospecting of the area, V. R. R. Khedker being in charge of the geological work. The staff of the Geological Survey was supplemented by the Damodar Valley Corporation's own geologists who were attached to the party, which is now carrying out a soil survey and prospecting the apatite-magnetite deposits, talc, kyanite, and other minerals occurring in the area.

The question of availability of sand for sand-stowing purposes being linked with the completion of the Damodar Valley scheme, a special investigation was undertaken to estimate the availability of sand in the event of the supply being reduced after the construction of the dams. A. B. Dutt, who with D. M. Sen and P. N. Ghosh carried out the investigation, came to the conclusion that sufficient sand would be

available for the Raniganj coalfield, but the quantity required for the Jharia field could not be met if the replenishment of the sand in the river was cut off by the construction of dams.

Rare Minerals Section

A Rare Minerals Section was started in the Geological Survey for carrying out field and laboratory investigations of radio-active minerals. This section has lately been handed over to the Atomic Energy Commission, some of the officers of the Department being on loan to the Commission. An officer is also now on loan to the Planning Commission.

Engineering Geology & Ground Water Investigations

The Engineering Geology and Ground Water Division, with J. B. Auden in charge of a number of officers, *viz.*, P. C. D. Hazra, G. C. Chatterji, K. K. Dutta, M. S. Bala-sundaram, S. P. Nautiyal, V. Subramanyam, A. K. Roy, V. S. Krishnaswamy, B. K. Baweja, R. K. Sundaram, A. Damo-daran, S. C. Awasthi, D. Venkataramanan, D. N. Sett, A. Mitra and others, has been actively engaged on 12 major dam projects including Marora, Ramganga and Rihand in the U.P., the Damodar Valley in Bengal and Bihar, the Mor Project in Bengal and Bihar, the Kosi dam-site in Nepal, the Hirakud site in Orissa, and the Bhakra Project in the Punjab; in each of the sites one or two resident geologists have been operating throughout the year. An officer was also on loan to the Ministry of Agriculture in connection with ground-water supplies.

The questions of ground-water supply throughout India, particularly in the Raniganj and Jharia coalfields, the Koraput district, Manipur State, Midnapore and Bankura districts, the Broach-Surat-Gujarat area, Kutch, many parts of Madhya Pradesh and the South Arcot and the Ceded districts of Madras, were attended to.

In addition to these enquiries, earthquake investigations were carried out in the case of the Makran earthquake of the

28th November, 1945 by V. P. Sondhi, and the recent Assam earthquake of the 15th August, 1950 by M. C. Poddar, B. Laskar, S. N. Sen, F. Ahmad and S. N. Puri.

Special Expeditions

During this period opportunity was taken to depute K. K. Dutta to join Dr. Church in a snow-survey in the Himalaya; A. G. Jhingran together with G. Kohli and B. N. Shukla to join the Danish expedition to the Spiti-Himalaya; and S. P. Nautiyal to join the party of scientists deputed to select a site for the proposed High Altitude Laboratory in the Himalaya.

The Ladies

It was during this period that the ladies came into their own, and several were appointed to the Library, and to the Geophysics and Chemical Sections, Mrs. K. Sarma (Assistant Geophysicist) being the first woman officer to hold a gazetted rank in the Department.

Social Activities

The Recreation Club of the Geological Survey of India, which started in 1944 with one football and no fixed playing ground, developed into a flourishing body. The achievements of its Sports section, particularly in football, earned for it a wide reputation in the local sporting world, and it has won a record number of trophies in the last three years. Its Entertainment section has reached almost professional standards of excellence, and the dramatic shows put on by it are of high quality.

It is a matter of satisfaction that the value of the Recreation Club has been recognised by the Government of India, from which it receives an annual token grant.

West's five years of Directorship close at the beginning of 1951. The work has proceeded with little variation from the lines chalked out in his first five-year plan, and sufficient experience has been gained to indicate the directions in which future work should be conducted. The second five-year plan

just prepared, based on the experience of the previous five years' work, should be an important contribution to the future development of the Department, which enters upon a new century in 1951.

The End of a Century

It is pleasant to recall that when Thomas Oldham took charge of the Department, he found himself confronted with a writer, a peon and a despatch box. One hundred years later the Department finds that even a five-storeyed building is too small to accommodate more than part of the total staff, which now comprises 400 technical and ministerial officers.

During its first hundred years, with a small staff, the Department has added not only to the knowledge of minerals of economic value, but has widened the horizon of scientific knowledge and broken new ground in the study of the science of the earth.

In the economic field its main pre-occupation has been with coal, and two coalfields were actually discovered by the Survey, sufficient alone to justify its cost. But attention has also been given to other minerals, and special *memoirs* on mica, manganese-ore, petroleum, bauxite, iron-ore and refractory materials have also been published.

Amongst the results which have influenced the course of geological science may be placed the recognition of the importance of deposits formed on land, the great Vindhyan and Gondwana systems and the Gangetic alluvium being revealed as land deposits. The recognition of the Upper Carboniferous glacial epoch in India, extending into Australia, South Africa and South America, which gave rise to the conception of the vast southern continent of Gondwanaland. The study of the great Assam earthquake of 1897, which led to the discovery of the three main types of earthquake waves, a discovery that has proved so fruitful in investigations regarding the internal structure of the earth. While the rich fossil mammalian fauna of the Siwalik hills, described in a

series of brilliant *memoirs*, adorn the museums of the world, throwing light on the evolution of the mammals and even of man himself.

Though primarily devoted to elucidating the geological history of India and examining its mineral resources, the Department has throughout maintained a truly international outlook on science, having had among its officers people of many nationalities: Austrian, German, French, Italian, British and Indian, and having published memoirs on the geology of countries neighbouring India.

After one hundred years, and with the dawn of a new era in the history of India, the need for the development and scientific utilisation of the country's mineral wealth, which has come to play such a vital part in improving the lot and in bringing prosperity within the reach of the common man, is felt more acutely than ever. The Geological Survey of India, in friendly collaboration with the sister organisations of the world, will, it is hoped, continue to play a vital rôle in advancing the boundaries of geological knowledge, and at the same time orientate its activities to the pressing material needs of a nation just reborn.

THE GAZETTED OFFICERS OF THE DEPARTMENT AT THE TIME OF THE CENTENARY

Director :

W. D. West, C.I.E., M.A., Sc.D., F.G.S., F.N.I., F.R.A.S.B.

Superintending Geologists :

- E. J. Bradshaw, B.A., B.A.I., M.S., (on leave preparatory to retirement).
M. S. Krishnan, M.A., A.R.C.S., D.I.C., Ph.D., F.N.I., (on deputation to India Bureau of Mines).
J. B. Auden, M.A., Sc.D., F.G.S., F.N.I., F.R.G.S.
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A. G. Jhingran, M.Sc., Ph.D.

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V. R. R. Khedker, M.Sc.
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G. C. Chatterji, B.Sc. (Hons.), A.I.S.M., (on deputation to U.S.A).
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Mukti Nath, M.Sc.
A. K. Roy, M.Sc.
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S. N. Sen, M.Sc.
G. N. Dutt, M.Sc.
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M. B. Ramachandra Rao, M.Sc., M.A.I.M.E.

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 D. Venkataramanan, B.Sc. (Hons.).
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